Electronic Engineering

ENTHOVEN

make

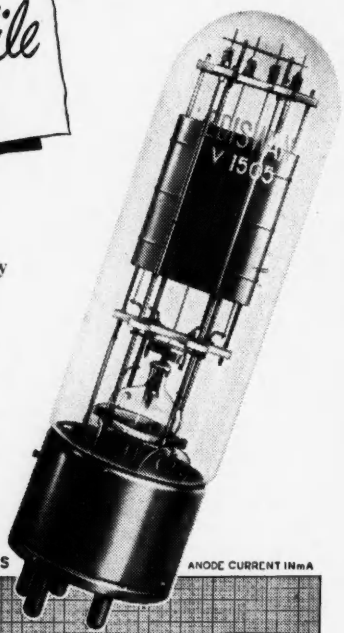
CORED SOLDERS

that ensure

FAULTLESS FLUXING

MARKETED BY ENTHOVEN SOLDERS LTD., • ENTHOVEN HOUSE, • 89, UPPER THAMES STREET, LONDON E.C.4.

DATA for the Designers File



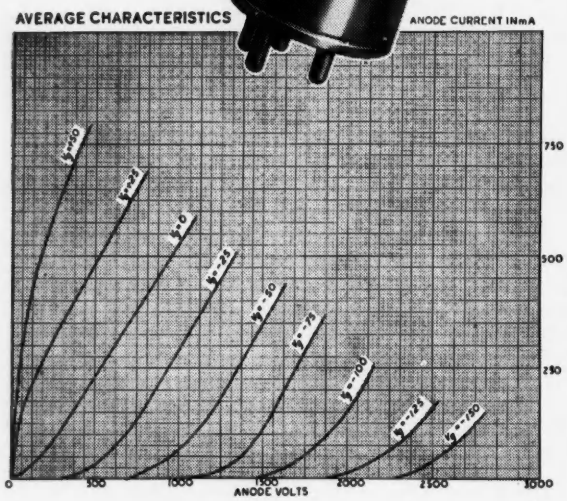
If you are designing Audio Frequency Amplifiers it is highly probable that you will need the Ediswan V. 1505.

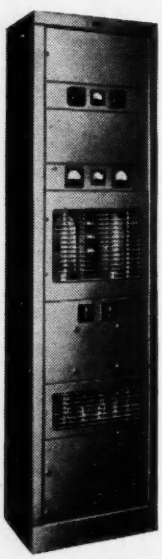
The Ediswan V. 1505 is a radiation cooled triode with a directly heated thoriated tungsten filament and anode dissipation of 275 watts. A pair of these valves in push-pull can provide an audio power output of approximately 1,000 watts. It is equivalent to the American Type 212E.

RATING

Filament Voltage	14 volts
Filament Current	6.5 amps
Maximum Anode Voltage	3,000 volts
Maximum Filament Emission	4 amps
Maximum Anode Dissipation	275 watts
Mutual Conductance (gm)	8*
Amplification Factor	16*
Anode Impedance (r_a)	2,000 ohms*
Maximum Operating Frequency at full rating	1.5 Mc/s
Audio Power Output	1,000 watts (2 valves)

* *Taken at V_a = 2,000 volts; I_a = 150 m/A.*





The Savage V.L.F. Amplifier incorporates the V. 1505

This amplifier has been designed to supply power at low frequency for Vibration Research and Testing. The continuous output rating is 1,000 watts at frequencies from 6 c/s to 2,000 c/s

EDISWAN

INDUSTRIAL AND TRANSMITTING VALVES

THE EDISON SWAN ELECTRIC CO. LTD.,
155 CHARING CROSS ROAD, LONDON, W.C.2
Member of the A.E.I. Group of Companies

EV120

CLASSIFIED ANNOUNCEMENTS

The charge for these advertisements at the LINE RATE (if under 1" or 12 lines) is: Three lines or under 7/6, each additional line 2/6 (The line averages seven words.) Box number 2/- extra, except in the case of advertisements in "Situations Wanted," when it is added free of charge. At the INCH RATE (if over 1" or 12 lines) the charge is 30/- per inch, single column. Prospectuses and Company's Financial Reports £14. 0s. 0d. per column. A remittance must accompany the advertisement. Replies to box numbers should be addressed to: "Electronic Engineering," 28, Essex Street, Strand, London, W.C.2. Advertisements must be received before the 14th of the month for insertion in the following issue.

OFFICIAL APPOINTMENTS

ADMIRALTY, TECHNICAL POSTS. The Civil Service Commissioners invite applications from men for about 40 posts in the Mechanical and Electrical Engineering Technical grades on production duties. 23 are in Grade II (Production Inspectors) and 17 in Grade III (Assistant Production Inspectors), The duties involve work in connexion with the manufacture, inspection, test and installation of a wide variety of mechanical, electrical and electronic equipment for H.M. Ships. Age at least 28 and under 45 on 1st August, 1953 for Grade II posts and at least 25 and under 35 on that date for Grade III posts, with extension for Regular service in H.M. Forces Candidates should preferably have the O.N.C. in mechanical and/or electrical engineering or have reached at least an equivalent standard of technical education. Possession of the H.N.C., or equivalent qualification, in the appropriate subjects will be an advantage. Candidates must have served an apprenticeship (or equivalent training) followed by appropriate engineering experience either in a Government establishment or in outside industry, of at least six years for Grade II posts and at least three years for Grade III posts. Inclusive salary scales. Grade II £581 (at age 28) to £733. Starting pay up to £623 at 30 or over. Grade III £483 (at age 25) to £628. Starting pay up to £549 at 28 or over. Somewhat lower in provinces. Promotion prospects. Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S 247/54. Completed application forms must be returned by 18th March, 1954 (15th April for candidates abroad).
W 3106

ADMIRALTY—ROYAL NAVAL SCIENTIFIC SERVICE. Engineers and Physicists (particularly with electronics) required for appointments in Experimental Officer and Assistant Experimental Officer grades in Experimental Establishments in London, Portsmouth, Weymouth and Gloucestershire Areas and Scotland. Candidates, British Subjects, must possess one of the following qualifications; University Degree in Science, Engineering or Maths., Graduate Membership of appropriate professional institute, Higher National Certificate, Final Certificate of five-year grouped course in relevant subjects at City and Guilds of London Institute or comparable institution Higher School Certificate, General Certificate of Education, Scottish Leaving Certificate, Scottish Universities Preliminary Examination, Northern Ireland Senior Certificate (all in appropriate subjects and at appropriate levels). London salary inclusive of pay addition (men) E.O.s. £681-£838. A.E.Os. (according to age) £274-£607. All appointments unestablished, but with some opportunities to compete for established posts. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A24/52/A. W 3097

B.B.C. requires limited number of Engineers (minimum age 21) of British Nationality for operations and maintenance duties at transmitter, studio, recording and television centres. Must be willing to serve anywhere in U.K. Experience in radio engineering desirable. Essential qualifications include University Degree, Higher National Cert. or equivalent in Electrical Engineering, Grad. Brit. I.R.E. with Maths, or C. & G. Final Certificate in Telecommunications. Promotion prospects. Starting salary £545 with annual increments to max. £755. Applications to E.E.C., B.B.C., London, W.1, quoting EX.2. W 3093

B.B.C. requires Technical Assistants for career in Operations and Maintenance Department, sound and television broadcasting. Knowledge mathematics, electricity, magnetism to G.C.E. Ordinary level; experience electrical/radio engineering advantage. Preferred age 20-25; older if experienced. Must be willing to serve anywhere in U.K. Starting salary £400 with annual increments to £635 and excellent prospects of promotion to Engineer grade with good technical training facilities. Possibility promotion after 2 years. Apply briefly stating; (1) Reference P.T.A. (2) Full Name (3) Address (4) Nationality (5) Age (6) Details of National Service or exemption (if under 26) (7) Qualifications (8) Relevant experience; to E.E.O., B.B.C., London, W.1, quoting EX 1. W 3089

COMMISSIONERS OF NORTHERN LIGHTHOUSES. Applications are invited for a post as an assistant on the Radio Engineer's staff for duties in connexion with the erection, maintenance, and development of radio navigational aids and communications. Applicants should be fully conversant with all classes of radio, radar, and electronic aids, and must have passed the graduate examination of the Institue of Electrical Engineers, or hold City and Guild groups Certificates, or equivalent. Salary scale £635 to £980 per annum, linked to age at entry between 25 and 34 years, maximum starting pay is at age 34: i.e., £880 per annum. Superannuation conditions are similar to those in the Civil Service. Applicants should apply in writing to the Secretary Northern Lighthouse Board, 84 George Street, Edinburgh, 2, stating age, qualifications, experience, and enclosing copies of testimonials. W 3101

ELECTRONICS TECHNICIAN for electrophysiological research wanted by University Department in Medical School. Duties to operate and maintain multi-channel amplifying and recording equipment, and to assist with development of new research apparatus. Wide knowledge of electronics techniques desirable, (EEG/EMG/CRO— photography). Salary in range £470-£545 according to experience, with superannuation. Apply, in writing, to the Secretary, Department of Physiology, Middlesex Hospital Medical School, London, W.1. W 3100

MINISTRY OF SUPPLY, R.A.E., Farnborough requires Electrical Engineers or Physicists to work on basic problems of generation and distribution of electric power in aircraft and of electro-technology arising from design and development of equipment. Interest in advanced electromagnetic circuit techniques or in physical properties of magnetic materials, desirable. Aptitude for experimental work essential. Minimum qualification — Higher School Cert. (science) or equivalent, but further training to Degree or H.N.C. standard in physics or electronic engineering may be an advantage. Salaries within ranges:— Experimental Officer (min. age 26), £649-£799; Assistant Experimental Officer £264 (age 18)-£576. Women somewhat less. Appointments unestablished. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A31/54A. W 3081

MINISTRY OF SUPPLY requires Senior Examiners at or near Birmingham, Bristol, Glasgow, London, Manchester, Sheffield to supervize inspection at works engaged in (a) aircraft and aero engines (b) radio and radar (c) instruments and electrical equipment or (d) materials (metallic and non-metallic). Qualifications: British of British parents. Recognized engineering apprenticeship or equivalent in radio/radar. Appropriate experience, O.N.C. or equivalent desirable. Salary within £592 (age 30)-£733. Not established but opportunities to compete for establishment may arise. Applications forms from E.A. 994 London Appointments Officer, Ministry of Labour and National Service, 1-6, Tavistock Square, London, W.C.1. W 3051.

MINISTRY OF SUPPLY, Royal Aircraft Establishment, Orfordness, Suffolk, requires Physicist with interest in electronics to lead section on application of radar to ballistic and other trials. Duties include responsibility for conduct of trials, development of techniques, and maintenance of ground radar equipment. Minimum qualification—Higher School Certificate (Science) or equivalent, but qualification in electronics desirable. Experience of operating and maintaining ground radar equipment essential. Salary within range, Experimental Officer (minimum age 26), £649-£799. Women somewhat less. Appointment unestablished. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting D.40/54-A. Closing date 12th March, 1954. W 3060

MINISTRY OF TRANSPORT AND CIVIL AVIATION. Radio technicians (men only) required at aerodromes and radio stations in various parts of U.K. Special training courses for keen technicians with basic qualifications. Interesting work in progress providing electronics aids to navigation. Prospect of permanent, pensionable posts. Rates of pay (London) from £335 p.a. at age 19, to £445 at 25, rising, subject to qualifying test to £540. Rates slightly lower for provinces. Candidates age 19 or over with practical experience in maintenance of radio or radar equipment should apply to any Employment Exchange, quoting Order No. Westminster 6627. W 3052

NATIONAL COAL BOARD invite applications for a number of senior appointments at their Central Research Establishment, Isleworth, Middlesex. This Establishment is undertaking research into the underground problems arising in the mining of coal, from winning it at the coalface to its arrival at the surface. The posts to be filled will be concerned with:— (a) an intensive fundamental examination of the mechanical properties of coal and the forces required to break it; (b) study of the fundamental principles of methods of getting coal from the seam, including cutting and ploughing, with the aim of devising new and improved methods; (c) applications of the fundamental knowledge gained in (a) and (b) above to the design of experimental machinery and the metallurgical problems involved in this and other mining practice; (d) fundamental study of the problems associated with the mining of coal including the conveying of coal by belts, the control and measurement of methane and dust and the measurement of stresses in coal and rock strata; (e) study of colliery electrical devices and systems, design of instruments for experimental work in the laboratory and in collieries, and the design of instruments for day-to-day use underground in collieries, including the measurement of dustiness and the detection of methane. Consideration will be given only to candidates having 1st or good 2nd class Honours Degree, or equivalent professional qualifications in Physics, Mining, Mechanical or Electrical Engineering, Metallurgy or Mathematics and having a proved record both of achievement in research and of ability to lead a team. Successful candidates will be appointed according to qualifications and experience, as follows:—Principal Scientist—(£1,895-£2,195) Senior Scientist—(£1,595-£1,895) Scientist 1—(£1,173-£1,595). Applications should be sent to Dr. L. C. Tyte, Director, Central Research Establishment II, c/o National Coal Board, Hobart House, Grosvenor Place, S.W.1, giving full particulars (in chronological order) of age, education, qualifications and experience (with dates). Original testimonials should NOT be forwarded. Closing date 12th March, 1954. W 3077

NORTHERN POLYTECHNIC. Holloway, London, N.7. The Governing Body invite immediate applications for appointment as full-time Grade "B" Assistant Lecturer in Telecommunications Engineering for the three-year full-time course in preparation for the Full Technological Certificate of the City & Guilds of London Institute in Telecommunications Engineering. A knowledge of radar and television engineering is desirable. Salary scale—£490 × £25 × £765, together with allowances in accordance with the Burnham Award. Form of application, together with full particulars, will be forwarded on receipt of a stamped, addressed foolscap envelope. R. H. Currell, Clerk. W 3094

PHYSICIST OR ELECTRICAL ENGINEER required by Ministry of Supply, Radar Research Establishment, Malvern, to work on problems of packaging for electronic equipment, involving investigation of cushioning systems under simulated Service hazards, and design of shock suspension systems for items of radar equipment having special packaging problems. Minimum qualification—Higher School Certificate (Science) or equivalent, but H.N.C. in physics or electrical engineering may be an advantage. Experience of experimental work

using electronic equipment desirable. Salary within range, Experimental Officer (min. age 26) £649-£799. Women somewhat less. Appointment unestablished. Application forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting A8/54A. Closing date 12th March, 1954. W 3041

PHYSICS SENIOR TECHNICIAN, Queen Mary College (University of London), Mile End Road, E.1. £460 by £20 to £560 p.a. plus London Weighting (£30 at 26). Pension scheme. Experience in university or industrial research laboratory preferable, with knowledge of electronics and/or high vacuum work and glassblowing. Letters only to Registrar, stating age, full details experience and present work. W 3112

RUNWELL HOSPITAL, near Wickford, Essex. Department of Electroencephalography. Trainee Technician required; of good general education; previous experience not essential. Salary as for Assistant Recordist: £175 at 18 years rising to £285 at 24 years. Prospects of upgrading after training and experience. Applications, with copies of testimonials or name of referees, to the Physician Superintendent. W 3062

THE COLLEGE OF AERONAUTICS. Lecturer in Experimental Electricity (Electronics), required to cover fundamental electronic circuits, including pulse circuits and their application to the measurement of non-electrical quantities. He will also assist in the development of the specialized electronic instruments required by all Departments of the College in their research work. Honours Degree in Physics or Electrical Engineering required with experience in at least one of the following fields:—airborne radio and radar systems; servomechanisms; electronic techniques in measurement and control. Salary within range £600-£1,000 p.a. with superannuation under F.S.S.U. and family allowance. Applications giving full particulars and containing the names and addresses of not more than three referees, to the Recorder, The College of Aeronautics, Cranfield, Bletchley, Bucks. Further particulars available. W 3083

WANTED. Technician—Electronic, with experience in electronic measuring apparatus. Whitley Council rates. Apply in writing to the Secretary, University College Hospital Medical School, University Street, London, W.C.1. W 3095

WAR DEPARTMENT requires lecturer at R.E.M.E. Training Centre, Arborfield. Qualifications:—Degree in Electrical Engineering or equivalent; experience in light current, radio or radar engineering essential. Salary in accordance with Burnham Technical Scale for Assistant B, with allowances for Degree, other special qualifications and for extra working time compared with Technical Colleges. Normal Teacher's Superannuation. Application forms from M.L.N.S., Technical and Scientific Register (K) 26 King Street, London, S.W.1, quoting ref. D.2/54A. Closing date 12th March, 1954. W 3085

WAR OFFICE require Assistant Mechanical Engineering Officer (Recruitment Grade Professional) at Donnington, Salop, to organize, control and supervise a workshop sector employing 30 to 40 civilians engaged on repair and calibration of electrical and electronic test equipment. Inclusive salary range £645 to £960 (Provincial). Applicants must be British of British parentage and be Corporate members of the Institution of Electrical Engineers or have passed or be exempt from Sections A and B of their membership examination, or possess a University Engineering Degree. Starting salary fixed according to age, qualifications and experience. Annual increments subject to satisfactory service. Post temporary but long term possibilities. Application forms quoting reference D423/53 A from M.L.N.S., Technical and Scientific Register (K), Almack House, 26 King Street, London, S.W.1. W 3084

SITUATIONS VACANT

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 *inclusive or a woman aged* 18-59 *inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order,* 1952.

A. C. COSSOR require Development Engineers for radar communications, Television and Instruments Projects in Development Division. Engineering Degree or equivalent: Professional qualification, experience in developing to Government and other specifications and directing work of development engineers. Senior positions. Write stating age, qualifications, experience and salary required to Personnel Manager, 22 Highbury Grove, N.5. W 3067

A. C. COSSOR LTD., require Junior Development Engineers for radar Communications, Television and Instruments projects. Engineering Degree or equivalent professional qualifications. Experience in developing equipment to Government and other specifications, an advantage. Write, stating age, qualifications, experience and salary required to Personnel Manager, 22 Highbury Grove, N.5. W 3063

A. C. COSSOR LTD., have vacancy in Development Division for Mechanical Designer. The requirement is for a professionally qualified man who has had considerable experience in design of light electrical engineering equipment to Government specifications and who is capable of directing a team of draughtsmen working on such equipment. Appointment Senior and salary and conditions of work as such. Write stating age, qualifications and experience to Personnel Manager, 22 Highbury Grove, N.5. W 3064

A. C. COSSOR LTD., have vacancy for Sales Engineer for work in the Communications field. Applicants should have had considerable experience in, and knowledge of the technical and operational aspects of H.F. and V.H.F. Communications equipment. Senior post with prospects, and successful applicant will report directly to Commercial Manager and be expected to be capable of making technical market appreciations and co-operating with Communications Development Engineers. Write, stating age, qualifications, and experience to Personnel Manager, 22 Highbury Grove, N.5. W 3065

A LARGE and well established electronic engineering company in the eastern suburbs of London invite applications from graduate electronic development engineers, age 28-33 for microwave and electronic development. Salary range £700-£1,000 per annum according to experience. The vacancies present attractive opportunities to men with good experience and qualifications. Company superannuation and insurance schemes in operation. Excellent conditions. Please reply in strictest confidence, stating qualifications and experience to Box No. W 3069.

A LARGE COMPANY engaged in system engineering and installation of Radar Equipment require a fully experienced Production Manager. This position is one of high responsibility, permanent, fully pensionable, and carries a substantial salary. Applications are invited from men who have an intimate knowledge of Radar engineering and, more particularly with recent experience of equipment of American origin in the 3 and 10 c.m. bands. This is a position for a man seeking wider scope for proven capabilities in a rapidly expanding organization. Full particulars of past record, age and salary required should be forwarded to the Personnel Manager, Box No. W 3071

AN ELECTRONIC ENGINEER is required in London for a variety of development work on oscillators and amplifiers—valve and magnetic. Salary by arrangement. Minimum starting salary £800 per annum. Write giving age and full experience to Box No. W 1942.

AN OPPORTUNITY occurs for a skilled instrument mechanic with electro-mechanical engineering background to join small but progressive scientific instrument manufacturers. A permanent post with good remuneration is offered to a man with an inventive mind and a capacity for hard work. Write giving full details to Box No. W 1943.

APPLICATIONS ARE INVITED for the position as Supervisor of the Test Department of a large established organisation engaged in expanding into a new factory on the South Coast. Essential qualifications are: Age 35-45 years. Good technical background in Electronics. Considerable factory experience of testing and control of staff, preferably in relation to Microwave Radar and Pulse Equipment. The appointment is subject to a probationary period in the existing organization, which will provide every opportunity to prove suitability. Write full details of education, experience and expected commencing salary to Box No. W 2999.

APPLICATIONS are invited from Engineers with production and/or research experience to undertake design and development of nucleonic equipment. Previous experience in micro-wave and pulse techniques an advantage. Vacancies are foundation posts in newly-formed laboratory and present first-class opportunities. Salaries in accordance with qualifications, experience and age. Apply in writing to Personnel Manager, Vidor-Burndept Limited, Erith, Kent. W 3039

APPLICATIONS are invited for positions in an Electronics Research Laboratory for work on new development in telecommunications systems and techniques. Academic qualifications and some experience an advantage. Applications should be addressed to the Personnel Manager, Standard Telecommunication Laboratories Ltd. Progress Way, Enfield, Middlesex. W 3116.

APPLICATIONS are invited for senior positions in the Research Laboratories of a large manufacturing organization. Candidates should be academically qualified with several years experience in microwaves. The work comprises the research of waveguides and microwaves antennas. Applications should be addressed to the Personnel Manager, Standard Telecommunication Laboratories Limited. Progress Way, Enfield, Middlesex. W 3114

A PROFESSIONALLY QUALIFIED ENGINEER with good experience of electronic servomechanisms is required for a new factory operating in North Staffordshire. Houses will be available for suitable applicants in the autumn of this year. Starting salary will be up to £1,000. Write to Box EE 890, L.P.E., 110 St. Martins Lane, London, W.C.2. W 3055

ARMSTRONG SIDDELEY MOTORS require an Electronic Engineer to assist in the building and development of equipment for testing rocket motors. Applicants should have Higher National Certificate or Degree in Physics or Electrical Engineering. Write giving full details to Reference DH4, Personnel Manager, Armstrong Siddeley Motors, Coventry. W 3040

A SENIOR ELECTRONIC ENGINEER is required who will be directly responsible to Head of Electronics Laboratory for one or more groups of development engineers engaged on Guided Missile Projects. Applicants should be over 30 and have considerable experience of at least one aspect of radar, communication, pulse, video or microwave work, together with a Degree or equivalent qualification. Commencing salary will be in the region of £800-£1,200 per annum according to experience and qualifications. A Pension Scheme incorporating life insurance is in operation and the Company is within 15 miles of London. Full details should be sent in strict confidence, to Box M B. 8141 A.K. Advertising, 212a Shaftesbury Avenue, London, W.C.2. W 3038

ASSISTANT DEVELOPMENT ENGINEER, experienced in design of "C" Core Transformers, Chokes, Toroidal Coils and various couplings for electronic equipment. Good salary and a permanent position with first-class working conditions in well-equipped laboratories. Good canteen, sports ground and social club. Five-day week. The premises are situated on the main bus route from Kingston and Guildford. Applicants must be of British nationality and should submit full details of age, qualifications and experience to the Joint Secretary, Cottage Laboratories Ltd., Fairmile Cottage, Portsmouth Road, Cobham, Surrey. W 3066

ASSISTANT ENGINEER required for laboratory work, including investigation of climatic effects on radio communication equipment. Experience of measurements on radio transmitters and receivers essential. Qualifications equivalent to Ordinary National Certificate or Inter B.Sc. standard desirable. Apply to Employment Manager, Ferguson Radio Corporation Ltd., Great Cambridge Road, Enfield, Middlesex. W 3061

ASSISTANT ENGINEER required for valve production department in Ruislip area. Applicants must have had previous experience of valve manufacture and a sound knowledge of high vacuum technique. Minimum qualifications—Inter B.Sc. or O.N.C. Apply by letter to Personnel Department, E.M.I. Ltd., Hayes, Middlesex. W 3057

A TELECOMMUNICATIONS FIRM in the North dealing with multi-channel carrier equipment for use on lines has a number of vacancies in the following fields: (1) Specialized Filter designers with experience in conventional type and quartz crystal filters. (2) Laboratory Development Engineers of Senior Grade. (3) Equipment Design Engineers. (4) Technical Writer for preparation of Handbooks. Ser-

CLASSIFIED ANNOUNCEMENTS
continued on page 4

the smallest single stage axial flow fan ever produced for electronic cooling and allied applications

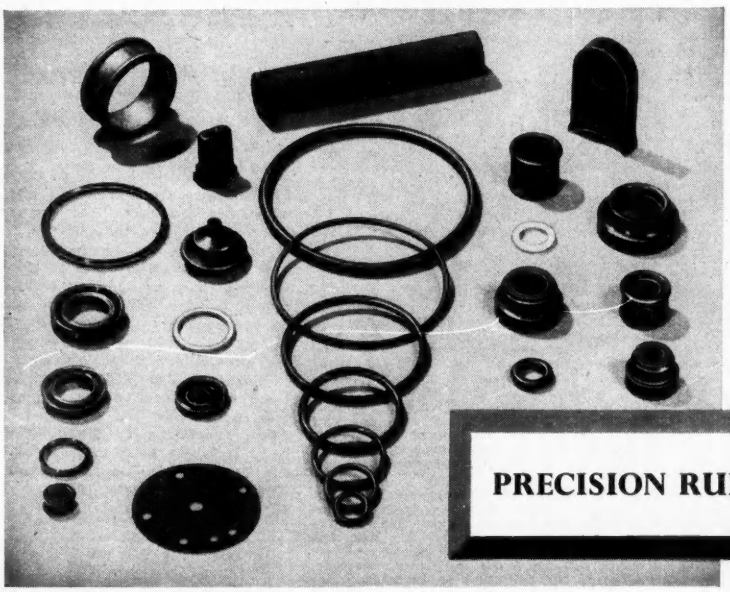
PLANNAIR
REGISTERED TRADE MARK

Type 2 PL 81 (2⅞" diameter)
OUTPUT : 44 CUBIC FEET OF AIR PER MINUTE AT 0.25" S.W.G.
MOTOR 24/28 VOLTS D.C.

Full details and specifications of all axial flow models from:—

PLANNAIR LTD., 140, PARK LANE, LONDON, W.1.

PHONE : MAYFAIR 4374.



*Specialists in Rubber and Synthetic Rubber Mouldings for Industry...

PRECISION RUBBERS LTD.

Manufacturers of Rubber Parts for
ROLLS-ROYCE LTD.

**Prototypes to Bulk Production*

PRECISION RUBBERS LTD · BAGWORTH · LEICESTERSHIRE · Telephone : BAGWORTH 241/2

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

vices experience an advantage. Age of secondary importance. The positions are on the established staff of the Company, with contributory pensions scheme, the usual staff conditions. Applicants are invited to write, giving full particulars of experience, qualifications and age to Box 532 Dorland Advertising Ltd., 18/20 Regent Street, London, S.W.1. W 3015

BUSH RADIO LTD., have a number of vacancies in their expanding laboratories at Plymouth. Applicants for posts (a) and (b) should preferably hold a B.Sc. or equivalent qualification in Physics or Engineering. (a) A Research and Development Engineer and a Junior Development Engineer for work in new television and circuit fields. Applicants should have interest and preferably experience in: — Television, network analysis, feedback, pulse techniques, optics. (b) Junior Development Engineers for interesting work on Government contracts. Experience in any of the following fields would be an advantage:—video, amplifiers, feedbacks, pulse techniques, microwave techniques. (c) A Development Engineer to initiate design and engineering layout of domestic radio receivers for the export market. Five years' experience of design of domestic receivers, and familiarity with working with drawing office and production departments, are required. Pleasant laboratory, good prospects, pension scheme. Interviews in London or Plymouth. Write, giving full details and salary required to the Chief Engineer, Bush Radio Ltd., Power Road, Chiswick, W.4. W 3103

CHIEF DEVELOPMENT ENGINEER required by Electrical Engineering Company in London. Must have production experience and possess qualifications enabling him to take control of all design and development activities. Experience in development of electrical measuring instruments, electro-mechanical and electronic devices essential. This is a well paid, permanent, pensionable, position. Apply in confidence with full details of age, qualifications and salary expected. Box No. W 3075.

CHIEF ENGINEER. MICROWAVE LINK DEVELOPMENT. Decca Radar Ltd. is creating an appointment, at the rank of Chief Engineer, to lead a growing division engaged in the development and exploitation of microwave link systems. The successful applicant must have had, in either this or closely allied fields, considerable industrial experience at a senior level. This experience must provide evidence of a faculty for leadership, organizing ability, and a capacity for drive. British nationality essential. A starting salary commensurate with the level of the appointment will be paid. Replies, which will be treated as strictly confidential, should be addressed to the Research Director, 2 Tolworth Rise, Surbiton, Surrey. W 191

CHIEF PLANNING ENGINEER required to take charge of process planning and tool design in an expanding Company engaged on electronic engineering. Directly responsible to the Chief Mechanical Engineer. Exceptional opportunity exists for an outstanding man with experience of radio or telephone production. University graduate preferred but technical qualifications are regarded as secondary to ability. Staff Pension Scheme. House may be available for successful applicant. Apply Personnel Officer, Airmec Limited, High Wycombe, Bucks. W 3096

DEVELOPMENT ENGINEER required for the design and development of equipment for interesting new project on television relay. Previous experience of T.V. carrier type telephone systems, or wide band amplifiers an advantage. Applicants with a Degree in Engineering or the equivalent preferred. Apply to Personal Dept. (SS/2) E.M.I. Ltd., Blyth Road, Hayes, Middlesex. W 3058

DEVELOPMENT ENGINEER required for Electrical Engineering Laboratory. Engineering Degree or equivalent. For work on all types of Electrical Measuring Instruments. Write, giving full details of education, experience and salary required to Employment Manager, Sangamo Weston Ltd., Great Cambridge Road, Enfield, Middlesex. W 3080

DEVELOPMENT ENGINEER required. Design experience of H.F. and V.H.F. transmitters essential. Good theoretical background and knowledge of production methods desirable. Apply with full details to Personnel Manager, Pye Telecommunications Ltd., Ditton Works, Cambridge. W 1934

DEVELOPMENT ENGINEER wanted for work on Radio and T.V. Good working knowledge of electronic circuitry and chassis layout essential. Some experience of mass production an advantage. Permanent and progressive position with good working conditions. Please write in the first instance to the Personnel Manager Mains Radio Gramophones Ltd., 359 Manchester Road, Bradford. W 1924

DRAUGHTSMAN required with experience of light mechanical or electro-mechanical design. Good prospects with expanding Company in Surrey. Five-day week. Pension scheme. Apply with full details to Box No. W 1932.

DRAUGHTSMEN required for design and production of light electro-mechanical apparatus. Varied and interesting work. Previous experience in the radio industry an advantage. Please apply, stating age and full details of past experience to Personnel Manager, Pye Telecommunications Ltd., Ditton Works, Cambridge. W 1935

ELECTRICAL test room assistants required with practical experience in assembling and calibrating precision instruments. Good prospects for men with the required qualities. Apply by letter to Cambridge Instrument Co., Ltd., Sydney Road, Muswell Hill, N.10. W 3059

ELECTRICAL ENGINEER, age 25-30, with good Degree and some experience in a research or development laboratory, is required for work on the application of electronic techniques to industrial measurement and control. The post is permanent, pensionable and offers good prospects. Applications in writing, giving full chronological details of qualifications and experience, together with age and salary required, should be addressed to Tube Investments Ltd., Dept. of Development and Research, Plume Street, Aston, Birmingham 6, quoting Ref. F.2. W 1930

ELECTRICAL ENGINEER for engineering development work. Minimum qualification H.N.C. or equivalent. Experience with the power side of high power radio transmission or similar work desirable but not essential. Age range 23 to 30. Permanent position. Write giving full details to Philips Balham Works, 45 Nightingale Lane, Balham, S.W.12. W 3091

ELECTRONIC DEVELOPMENT ENGINEERS. Vacancies exist for the following:— (a) Development Engineer with Degree in Physics or Electrical Engineering, preferably with experience of feedback amplifiers or light servo-mechanisms. (b) Junior Development Engineer with Degree or H.N.C. Some experience in industry desirable but not essential. Interesting work on varied development projects in modern laboratories in Surrey. Five-day week. Pension scheme. Apply with full details to Box No. W 1931.

ELECTRONIC ENGINEER required for laboratory of Capacitor manufacturers. To deal with test instruments, standards and measurements for development work. Experience of RCSC specifications an advantage. Location E.18. Write Box No. W 1938.

ELECTRONIC ENGINEER. Unique opportunity for young man with vision, suitable technical qualifications and experience. Age range 25-30. Project covers application of a metal detecting technique for use in the industrial and allied fields. Ability to conduct technical selling a necessity and some commercial knowledge desirable. Only individuals of character and those fitted for pioneer work involving some travel at home and abroad should apply for an opening possessing unusual scope for initiative and personal development. Box No. W 1954.

ELECTRONIC ENGINEER required, preferably young with knowledge of stroboscopic electronics, to take charge of new small department to produce equipments for machines. Pleasant position at works in country. Please state in confidence past experience, salary required and full particulars to Leslie Hartridge Ltd., Buckingham, Bucks. W 1953

ELECTRONIC ENGINEER required by Birmingham Company handling wide range of Industrial and Laboratory Instruments. Applicants (age 25-35) must possess Degree in Electrical Engineering or Membership of I.E.E.; be capable administrators, experienced in application engineering and able to expand sales. Salary £750-£1,000 according to age and experience. Pension scheme. Box. No. W 1937.

ELECTRONIC ENGINEERS required by The General Electric Co. Ltd., Brown's Lane, Allesley, Coventry, in their Development Laboratories for work on: (a) Trials team in connexion with Guided Weapons; one Senior Engineer also three Engineers. (b) Servo-mechanisms; one Engineer. (c) Pulse Circuitry; three Engineers. (d) Microwave Circuits; one Engineer. (e) Test Equipment; two Engineers. (f) General Radar Circuit Development; two Engineers. (g) Power units, including electronic stabilizers and rectifier systems; one Engineer. (h) Magnetic Amplifiers; one Engineer. Applicants, preferably with a Degree or an equivalent qualification, should have had at least two years' experience in the development and engineering of Service equipment as well as experience in one of the above. Reply stating age, qualifications and experience to the Personnel Manager, Ref. R.G. W 3006

ELECTRONIC ENGINEERS are invited to apply for senior posts of exceptional interest and opportunity with Decca Radar Ltd., to work in their laboratories on an extensive and expanding programme of link and radar development. Applicants must have had responsible development experience in the electronic field. Posts are permanent and pensionable. Good starting salaries and considerable prospect of advancement. Write quoting Ref. RLA/17, The Research Director, Decca Radar Ltd., Research Laboratories, 2 Tolworth Rise, Surbiton, Surrey. W 3104

ELECTRONICS DEVELOPMENT ENGINEERS (senior and junior) required for electro-medical and industrial equipment development. Applications should be made to the Chief Engineer, General Radiological Limited, 15-18 Clipstone Street, London, W.1, giving full details of qualifications, experience and salary required. W 1936

ELLIOTT BROS. (LONDON) LTD., require Senior Electro-mechanical engineer with good academic and professional qualifications and experience of modern production methods for development of air-borne equipment including gyroscopic devices and instrument servo mechanism. Applicants should have at least five years' experience in this class of work. Excellent prospects. Write fully stating age, experience and salary expected to Personnel Manager, Century Works, Lewisham, S.E.13. W 3099

ENGINEER required to undertake the design of electronic instruments. The successful candidate will be required to accept responsibility for development to the production stage Degree or equivalent preferred. The salary will be commensurate with qualifications and experience. Apply in writing to Advance Components Ltd., Back Road, Shernhall Street, London, E.17 W 1940

ENGINEER required for the developing of H.F. transmitting equipment. The Applicant filling this post will be responsible for the supervision of projects to the production stage and will work under the general direction of the Senior Engineer. B.Sc. or equivalent essential. Junior Engineers. Duties will include development work on communication equipments in the H.F., V.H.F. and U.H.F. fields. These vacancies will call for men with design experience and with training to Higher National Certificate level. Good working conditions in modern factory with sports, social and canteen facilities. Excellent opportunities for further study. Single board available. Apply to Personnel Manager, Pye Telecommunications Ltd., Ditton Works, Cambridge. W 1941

ENGINEER—25-30, with Degree or H.N.C. in mechanical engineering and experience in the design of servo and hydraulic control systems, is required for interesting development work. Position carries responsibility and scope for

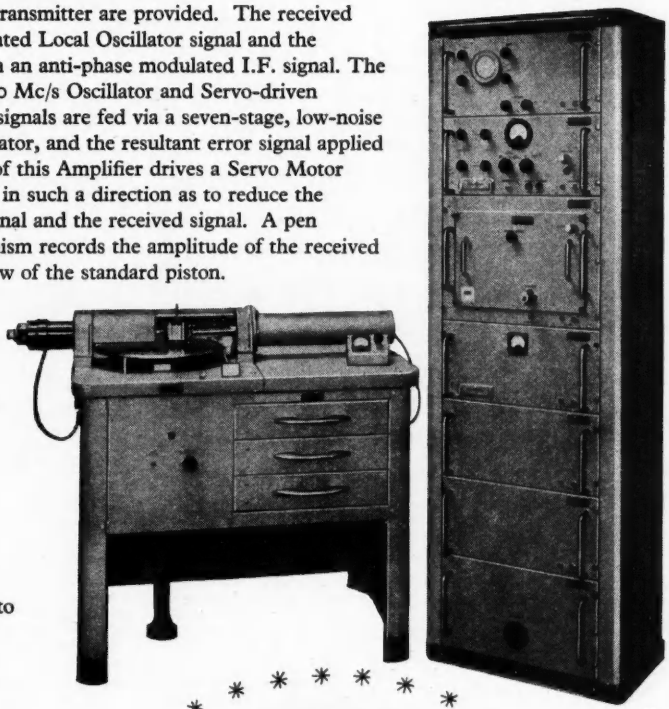
CLASSIFIED ANNOUNCEMENTS
continued on page 6

An Equipment for recording

ANTENNA RADIATION PATTERNS

THIS equipment has been developed by EKCO Electronics to automatically record the radiation patterns of any centimetric antenna. The antenna under test is mounted on the roof of a rotatable trailer and illuminated by a fixed transmitter. The amplitude of the received signal is then continuously plotted against the angular traverse of the trailer.

ALL the equipment except the transmitter unit is mounted in the trailer and remote controls for the transmitter are provided. The received C.W. signal is mixed with a modulated Local Oscillator signal and the resultant I.F. output combined with an anti-phase modulated I.F. signal. The reference signal is derived from a 30 Mc/s Oscillator and Servo-driven Piston Attenuator. The combined signals are fed via a seven-stage, low-noise I.F. Amplifier to a balanced Modulator, and the resultant error signal applied to a Servo Amplifier. The output of this Amplifier drives a Servo Motor which moves the Piston Attenuator in such a direction as to reduce the difference between the reference signal and the received signal. A pen attached to the piston drive mechanism records the amplitude of the received signal in terms of the attenuation law of the standard piston.



FACILITIES are available for plotting either on Cartesian or polar co-ordinate graph paper. The amplitude scale in each case is 10dB per inch with a maximum travel of 65dB and the Cartesian co-ordinate paper can be run at rates corresponding to 2 or 5 degrees per inch.

THE Standard Equipment covers the frequency range of 9300 to 9500 m/c. The frequency changer section is a plug-in unit and other frequency ranges can be covered to special order.

PHYSICAL SOCIETY EXHIBITION
STAND 43 April, 8th – 13th

ANTENNA PATTERN RECORDER TYPE E59.

EKCO ELECTRONICS LTD. EKCO WORKS, SOUTHEND-ON-SEA, ESSEX

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

future progress in this field. Applicants should write with full details to Personnel Department (ED/156), E.M.I. Engineering Development Ltd., Hayes, Middlesex. W 3078

ERICSSON TELEPHONES LTD., have a number of vacancies in their Research Laboratories in connexion with Electronic Switching and Computing. The posts will carry starting salaries between £600 and £1,000 according to age and experience. (a) Electronic Circuit designers of all grades. Applicants should have Degree or equivalent, and several years' experience in the design of electronic circuits. (Reference L.E./1). (b) Electronic equipment engineers with experience in the layout and mechanical design of electronic instruments and equipment in the radio, radar or communication fields. They will be required to co-operate with the circuit designers in the early stages and may ultimately be responsible for development to the production stage. (Reference LE/2). Applicants who should be British born and between 25 and 35 years of age, should write quoting the reference above and giving details of age, experience, academic or other training, and required starting salary to the Personnel Officer, Ericsson Telephones Ltd., Beeston, Nottingham. W 2751

EXPERIENCED ENGINEERS are sought by an established and well-known organisation, to assist in the development of wide band microwave telecommunication systems. Considerable effort will be put into this project and the appointments offer exceptional opportunities for advancement. As the successful candidates will be expected to make an immediate contribution it is essential that applicants should have had several years' research or development engineering experience in one or more aspects of the above field. Please apply, quoting ref. HBB to Box No. W 3025.

EXPERIENCED MICROWAVE ENGINEERS are invited to apply to Decca Radar Ltd., to join the Company in its extensive work in a wide field of microwave link and radar development. The company offers excellent starting salaries and first rate opportunities for men to exploit their initiative and to rise rapidly to responsible posts. Graduates without industrial experience who are prepared to undertake intensive training are also invited to apply for junior posts. Applicants must be of British nationality. Apply Ref. RLA/14, Decca Radar Ltd., Research Laboratory, 2 Tolworth Rise, Surbiton, Surrey. W 3105

FERGUSON RADIO CORPORATION LTD., offer exceptional opportunities for Draughtsmen wishing to make their career in the world of electronics, television and radio. Candidates preferably experienced in the Radio and Television industries, must have knowledge of mass production methods and workshop practice. Familiarity with Ministry requirements an advantage. Good Salaries: Pension Scheme. Well equipped Drawing Offices and good working conditions. Apply: Employment Manager, Ferguson Radio Corporation Ltd., Great Cambridge Road, Enfield, Middlesex. W 2946

EXPERIENCED Radio Testers and Inspectors required for production of communication and radio apparatus. Also Instrument makers wirers and assemblers for Factory Test apparatus. Apply Personnel Manager, E. K. Cole Ltd., Ekco Works, Malmesbury, Wilts. W 146

EXPERIENCED TECHNICIAN required for installation test and servicing of industrial electronic equipment. Good salary offered. Pension scheme. Full details to Box. No. W 1951.

FERGUSON RADIO CORPORATION LTD., require Senior and Junior Mechanical Engineers to join groups engaged on the development of Radio and Television Receivers for mass production. In the case of Senior Engineers, experience in the same or closely allied fields is essential. Successful applicants will be eligible for the Company's Pension Scheme. Applications specifying the post for which application is made and giving full particulars as to age, qualifications and experience, etc., to Employment Manager, Ferguson Radio Corporation Ltd., Great Cambridge Road, Enfield, Middlesex. W 3053

GLASS BLOWER required by Ferranti Ltd. (Wythenshawe) for work on experimental microwave valves. Experience is required in normal laboratory glass-blowing and metal-to-glass sealing techniques. Salary according to age and experience in the range £500/£800 per annum. The Company has a Staff Pension Scheme. Application forms from Mr. R. J. Hebbert, Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote reference ROW. W 2977

HIVAC LIMITED, manufacturers of specialized thermionic and electronic devices offer interesting posts for scientists, engineers and technicians in their expanding organisation on research and development projects in valves, cold cathode tubes and transistors. Previous experience in these fields, although an advantage, is not essential, but a sound education and an active and inquiring mind are. Encouragement will be given, wherever possible, to the publication of original work. The company is a member of a major communications Group and the posts, which are available for both senior and junior applicants are pensionable and offer scope for advancement. There is a five-day working week. Applications in writing, which will be treated in strict confidence, stating age, education, qualifications and salary expected, should be addressed to the Engineer-in-Chief, Hivac Limited, Greenhill Crescent, Harrow, Middlesex. W 3070

HYSTERISIS MOTORS—Vacancy for first-class electrical engineer with Degree in physics or electrical engineering with experience in the design and development of hysterisis and small high-frequency electric motors: also small electrical mechanisms. Salary £900-£1,000 with pension scheme. Please write in detail, quoting reference G, to Personnel Manager, de Havilland Propellers Ltd., Manor Road, Hatfield, Herts. W 3113

INDUSTRIAL ELECTRONICS SALES MANAGER. A large and progressive organisation has an immediate vacancy for a Sales Manager to take charge of promotion of the sale of manufacturing and engineering services to industry in the Electronics field. The Company is expanding its activities in the field of high quality electronic design and manufacture, particularly in the sphere of industrial electronics, and to this end requires the services of a top grade Sales Manager with experience in this field, and extensive contacts in industry. Good technical knowledge would be an advantage, but professional engineering qualifications are not essential. This post is permanent, pensionable, and commands a high initial salary with excellent prospects of advancement to the right man. Only a man of exceptional drive and initiative can hope to fill this post adequately. The successful applicant is assured of the backing of a production organisation of the highest order coupled with adequate engineering facilities. Replies will be handled in the strictest confidence. Write to Box No. W 3049.

IBM UNITED KINGDOM requires young engineer or physicist with Degree or equivalent qualification and electronic experience. Knowledge of digital computer design desirable. Apply in writing stating qualifications and salary required to Box No. W 1945.

JUNIOR ELECTRONIC ENGINEER required for development and testing of a wide range of electronic measuring instruments. Previous experience desirable but not essential. Excellent prospects for rapid advancement in young and expanding organisation. Rivlin Instruments, 7A Maitland Park Villas, N.W.3. W 1926

JUNIOR ELECTRONIC ENGINEERS required for work in the vibration test laboratory on Guided Weapon Projects. Vacancies are as follows:—(Ref. 1) For development and construction of audio-frequency measuring equipment. H.N.C. standard is required. (Ref. 2.) For maintenance of audio-frequency test equipment. Must be capable of servicing oscillators, power amplifiers, oscilloscopes, stabilized power supplies, etc. Similar experience essential. Good salary, bonus and pension scheme. Excellent opportunity for entering the rapidly expanding field of vibration research. Five-day, 38-hour week. Full details should be sent to the Assistant Manager, The Fairey Aviation Co., Ltd., Dept. EE. Research and Armament Development Division, Heston Aerodrome, Hounslow, Middlesex. W 3043

JUNIOR ENGINEER required for long-term developments in the communication equipment and general electronics development field. Applicants should be between the ages of 21 and 26, and should possess a Degree or have had at least three years' laboratory work in the domestic radio or communication fields. These vacancies possess excellent opportunities for keen and ambitious young men. A generous salary will be paid to the selected applicants. Please reply, giving details of qualifications and experience, to Box. No. W. 3068.

LABORATORY ENGINEER required for design and development of H.F. testing equipment for coaxial and telephone cables. Engineering or Physics Degree essential and approximately two years experience desirable. 23 to 26 years of age. Salary according to qualifications and experience. Write stating qualifications and experience to Personnel Manager, Standard Telephones & Cables Ltd., North Woolwich, E.16. W 3092.

McMICHAEL RADIO LTD. require Senior and Junior Engineers in their equipment division laboratory at Slough. Training and experience in the field of applied electronics (including communications) and experience of working with Government Departments are the chief qualifications required. Write stating age and full details of training, qualifications and experience to the Chief Engineer, Equipment Division, McMichael Radio Ltd., Slough, Bucks. W 157

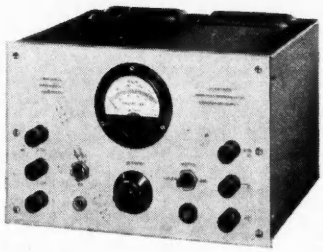
METHODS ENGINEERS required for senior positions in expanding manufacturers, S.E. London. Principal duties concern radio and TV line layout: preference given to those with job study experience. To right applicants these will prove permanent and progressive posts with commensurate salaries. Write in confidence, with full particulars and salary required. Box D.C. 1786 A. K. Advertising, 212a Shaftesbury Avenue, London, W.C.2. W 3079

MURPHY RADIO LIMITED have vacancies in the Electronics Division Laboratories for qualified engineers to design and develop the following: 1 V.H.F. and U.H.F. Communications equipment. 2 Airborne and ground radar equipment. 3 Computing devices and servo systems. 4 Nucleonic equipment and measuring instruments. The salary range is £600 £1,100 per annum depending upon experience. Further posts are available to engineers of H.N.C. standard or equivalent having less experience, the salary range being £450 to £650 per annum. Applications giving age, full details of qualifications, experience and salary required, should be forwarded to Personnel Department (E.D.L.), Murphy Radio Limited, Welwyn Garden City, Herts. W 3807

OPPORTUNITY offered to an Electronic Engineer capable of holding a responsible post as an instrument designer. An engineering Degree and experience covering a wide range of frequencies are advantages which will be reflected in the salary offered. Box. No. W. 1939.

CLASSIFIED ANNOUNCEMENTS
continued on page 8

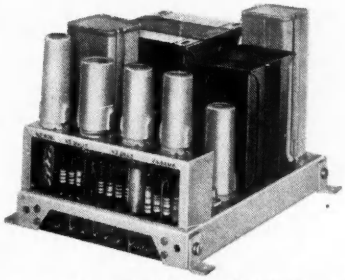
FOR POWER SUPPLIES



Model SRS 153 (*Solartron Vari Pack*)

D.C. Output Voltage:	0-500 volts positive or negative.
D.C. Output Current:	100 m/a up to 350 volts. 50 m/a up to 450 volts.
A.C. Output:	4 or 6.3 volts at 3 amps.
Ripple:	0.2 volt maximum.

Price £33

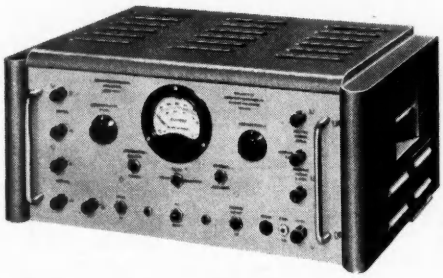


Mode lSRS 154B (*High Stability Power Unit*)

D.C. Output Voltage:	250 volts +Ve or −Ve, 0-50 m/a.
Stabilisation:	0.025% for a ±10% mains change.
D.C. Resistance:	0.5 ohm.
A.C. Impedance:	0.05 ohm from 40 c/s to 100 Kc/s.

Ripple and Noise Content. Less than 200 microvolts.

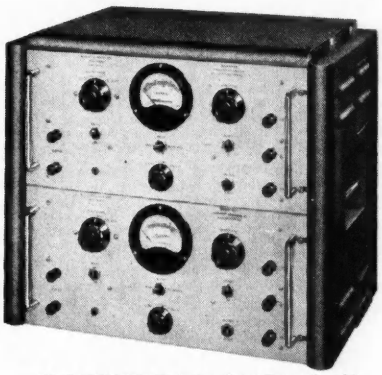
Price £28 15s. 0d.



Model SRS 151A (*Regulated Power Supply*)

D.C. Output:	20-500 volts +Ve or −Ve, 0-300 m/a.
Stabilisation:	1 part in 400 for ±10% mains change.
Source Impedance:	3 ohms.
Hum Level:	8 millivolts maximum.
A.C. Output:	Two 6.3 volt outputs at 5 amps.

Price £104



Model SRS 152 (*Twin Regulated Power Supply*)

D.C. Output Parallel Condition:	0-500 volts +Ve or −Ve, 0-300 m/a.
D.C. Output Series Condition:	0-1000 volts +Ve or −Ve, 0-150 m/a or 0-500 volts +Ve and 0-500 volts −Ve.
Stabilisation:	0.2% for a ±10% mains input change.
Ripple:	Less than 8 millivolts.
A.C. Output:	Two 6.3 volt outputs at 5 amps.

Price £165

SPECIFY

SOLARTRON

Write for full details of these and other new products.

SOLARTRON LABORATORY INSTRUMENTS LIMITED,

Solartron Works Queens Road Thames Ditton Tel: Emberbrook 5611 PBX

SITUATIONS VACANT (Cont'd.)

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

PHYSICISTS AND ELECTRONIC ENGINEERS required for research work on electronic tubes and circuit development. Applicants should have a good degree in Physics or Electrical Engineering. Vacancies offer good prospects and conditions, and are superannuated. Apply to Personnel Dept. (R/JDM) E.M.I. Research Laboratories Ltd., Hayes, Middlesex. W 3086

PRECISION ENGINEERING—The Instrument Design Group of **The English Electric Co.,** Luton Division, is being expanded and the services are sought of a Senior Designer to head up the unit. The work involves design and development of high precision equipment, such as gyroscopes and similar precision equipment, to be used in conjunction with the Guided Weapons development programme. The position holds considerable responsibility and will be covered by an appropriate salary. Applications from qualified engineers for other positions in this group will also be welcomed. Applications, quoting reference 1142C, to Dept. C.P.S., 336/7 Strand, W.C.2. W 2970

PRODUCTION ENGINEERING (RADAR). Production Superintendent (Ref. P.S.) required for rapidly developing satellite of a well-known Company handling the production and installation of radar equipment. The man we seek will be fully experienced and capable of taking supervisory control of the output of a well organized assembly line labour force in a well equipped factory producing high priority equipment for important radar installations. The position is permanent. Applications for this position which would carry a liberal salary and would be in the Huntingdonshire area, should be addressed to The Personnel Manager, Box No. W 3072.

PYE TELECOMMUNICATIONS LTD., Ditton Works, Cambridge, will shortly have a limited number of vacancies for Junior Engineers. Experience in V.H.F. design and engineering is essential. Salary according to qualifications and experience. Modern factory. Sports, social and canteen facilities. Single board available. Please apply, stating age, qualifications and experience to Personnel Manager. W 1933

RADAR ENGINEERING. Two important vacancies exist on the permanent staff of an influential Company concerned with high priority production and installation in Huntingdonshire of radar systems, much of which involves American equipment. Both positions are progressive, pensionable and well salaried. The first is for a Production Controller (Ref. P.C.), who should already have had first-class experience of a similar nature and be thoroughly conversant with radar and/or radio engineering production of a high order. He will be a competent executive who knows assembly line production, can handle production layouts, in fact, all aspects of this highly important function. The second vacancy concerns a Production Engineer (Ref. P.E.) who has already established his abilities in an efficient, well organized production unit, and who has an intimate knowledge of detailed engineering production in the radio/radar field. Apply, quoting above references, in strict confidence to Box No. W 3073.

RADAR ENGINEERING ASSISTANT required for development work (including circuit design) under the general guidance of a senior engineer. Must have some experience in radar techniques and, preferably, be between 25 and 35 years of age. Written application, giving details of experience and technical qualifications, should be addressed to Personnel Department, Kelvin & Hughes Ltd., New North Road, Barkingside, Essex. W 3108

RADIO PHYSICIST required by well known and established firm of Electrical and Mechanical Engineers and Scientific Instrument Makers in the London area, to take charge of development of electronic equipment for industrial and Services application. Age 30-40. Good Honours Degree in Physics with electronic bias. At least seven years Post Graduate experience of research and development in electronics. Excellent conditions and prospects for first-class man. Apply, stating qualifications and salary to Box No. W 1952.

REQUIRED urgently by progressive Company in Stevenage. (a) Junior Development Engineers with experience of pulse techniques and/or communication equipment used to working to Ministry specs. H.N.C. or equivalent. (b) Designer Draughtsman with experience of layout and mechanical design of electronic equipment. O.N.C. (c) Junior Planning Engineer, youth with initiative and common sense outlook, required for training as planning engineer. Experience in a light mechanical or electrical engineering works would be an advantage. (d) Electrical/Electronic Wireman used to reading circuit diagrams laying out cable loom, etc., able to work on own initiative. (e) Detail Fitters—used to light mechanical engineering, sheet metal work, etc., capable of manufacturing prototype models as well as small production quantities. (f) Mechanical Inspector familiar with A.I.D. and I.E.M.E. procedure, used to inspecting mechanical details of electronic equipment, jig checking, etc. (g) Electrical inspectors familiar with A.I.D. procedure capable of working on own initiative O.N.C. preferred but consideration will be given to others with suitable practical experience. Interested applicants are invited to write to the General Manager, Messrs. Fleming Radio (Developments) Limited, Caxton Way, Stevenage, Herts. Saturday interviews can be arranged. Housing will be provided for sucessful applicants after a probationary period. W 1946

SCIENTIFIC OFFICER required for the Electron Microscopy Laboratory of British Insulated Callender's Cables Limited at 38 Wood Lane, Shepherds Bush, W.12. Candidate should be a graduate in Physics and have some experience of vacuum technique. Some knowledge of photography and electronics is desirable. Candidate must have a good eye for fine work and a steady hand. Five-day week. Pension Fund. Apply in writing to Staff Officer, British Insulated Callender's Cables Limited, 21 Bloomsbury Street, London, W.C.1. W 3074

SENIOR BROADCAST RECEIVER designer for leading radio manufacturer capable of assuming responsibility for presentation and mechanical design and with some knowledge of broadcast receiver circuits. Extensive experience of tool-room and machine-shop practice essential. Reply in confidence with full details of qualifications and experience and salary required. Box No. W 3042.

SENIOR ENGINEER and a Junior are required by a progressive firm of electronic instrument manufacturers for interesting development work on important projects. Experience in the design of small signal frequency transformers an advantage. Scope for initiative and self expression. Applicants should possess a Degree in physics or the equivalent and should have industrial experience and a practical mind. Pension scheme. Salary and prospects will be good for the right men. Apply Box No. W 2960.

SENIOR ENGINEER required by the The English Electric Valve Co., Ltd., Chelmsford, for work on high powered magnetron and klystron development for work in the U.H.F. field. Previous experience essential, and a commensurate salary will be paid. Please apply to Dept. C.P.S., 336/7 Strand, W.C.2., quoting Ref. 419L. W 3082

SENIOR ELECTRONIC ENGINEER required to lead a group working on advanced valve applications. The applicant should have a sound working knowledge of modern circuit techniques in the Electronic field, particularly with application to radio and television and should hold a Degree or equivalent. Essential qualities are an aptitude for original experimental work and an ability to guide the work of others. Apply in writing to Personnel Dept., M.O. Valve Co., Brook Green, Hammersmith, W.6, stating age, qualifications and details of experience. W 3111

SENIOR TELEVISION DEVELOPMENT ENGINEER required by well-known radio and television manufacturer in London area. Applicants must have a wide experience in development for mass production of modern commercial radio and television receivers. A good salary will be paid to a person possessing drive and organizing ability and capable of carrying through projects from development to production stages, under the supervision of the chief engineer. Kindly state full particulars of technical education and experience to Box No. W 3098.

TECHNICAL AUTHOR (Male) age 21-25 required on production of handbooks for domestic radio, T.V. and other Electronic equipment. West Middlesex. Write giving full details to Box No. W 3110.

TECHNICAL CORRESPONDENT to deal with technical and sales letters and follow up inquiries. Detailed information on technical matters will be given by Laboratory, but applicants must have wide enough knowledge to understand general radio technical queries. Must be able to write good letters, first class English essential. Write full details experience, qualifications, age and salary required. Goodmans Industries Limited, Axiom Works, Wembley, Middlesex. W 1929

TECHNICAL WRITER required, to prepare technical instructions and information for Electrical Instruments, and equipment used in Aircraft Industry. Write in first place full details, age, etc., Employment Manager, Sangamo Weston Ltd., Cambridge Road, Enfield, Middlesex. W 2913

TECHNICIANS required for laboratory and inspection duties in connexion with design of quartz and synthetic crystals and associated circuits. Applicants should be between 24 and 35 years of age, and preferably have had some industrial or services experience in Radio techniques. Salary £500 to £700 per annum dependent upon qualifications and experience. The position is tenable in South West Lancashire and is on the established staff status with contributory Pension Fund and usual staff conditions. Applicants are invited to write to Box No. 530, Dorland Advertising Ltd., 18/20, Regent Street, London, S.W.1, giving full particulars of their qualifications, experience and age. W 3004

THE ENGLISH ELECTRIC CO., LTD., Stafford, has vacancies for the following staff:—(1) Switchgear Sales Engineers. Previous experience of this type of work is essential. Ref. 250E. (2) Electronic Test Engineers. Knowledge and experience of testing control schemes and involving electrical servomechanisms is desirable, but applications will be considered from otherwise suitably qualified Engineers. Ref. 942D Candidates who should have good technical qualifications are invited to apply to Dept. C.P.S., 336/7, Strand, W.C.2, quoting appropriate reference number. W 3102

THE GENERAL ELECTRIC CO. LTD., Brown's Lane, Coventry, require Senior and Junior Electronic Development Engineers for work on Guided Weapons and like projects, particularly in the field of Microwave and Pulse Applications. Mechanical Development Engineers, Designer Draughtsmen and Draughtsmen, preferably with experience of Radar type equipments, also required for the above projects. Salary according to age, qualifications and experience. Apply by letter stating age and experience to the Personnel Manager (Ref. R.G.). W 169

THE RESEARCH LABORATORIES of the General Electric Company are establishing an organization near Adelaide, South Australia, for trials and further development of guided weapon equipment, which is at present under development in this country. Applications are invited from GRADUATES with suitable qualifications to fill the following vacancies:—(a) An Engineer to take charge of trials teams. (b) An Engineer or Physicist to take charge of a laboratory engaged on the development and use of special test equipment. (c) A Physicist or Mathematician to take charge of a small group on the analysis and assessment of trials results. Candidates for post (a) and (b) should have had experience of modern radar or similar equipment, and of supervizing the work of a small number of experimental staff; those for post (c) should have an interest in the modern methods used in the interpretation of experimental results, together with the ability to write clear, concise reports and supervize the work of a small number of assistants. The successful applicants will receive training in England on the work they will be doing ultimately in Australia, and will be transferred to that country in due course. Details of conditions of employment, housing, passages to Australia, etc., will be given to candidates when interviewed. Reply, quoting ref. EF/AUST, to the Staff Manager, G.E.C. Stanmore Laboratories, The Grove, Stanmore Common, Stanmore, Middlesex, stating age, qualifications and experience. W 3076

THE STEEL COMPANY OF WALES LIMITED (Tinplate Division) Trostre Works. Electronic Technician required for maintenance of various types of Industrial Electronic control. Consideration will be given to applicants without experience in the above, but with

CLASSIFIED ANNOUNCEMENTS
continued on page 10

The Dalic Process of Electrodeposition

Renovating the zinc protective coating of a propeller blade on site at Air France.

The DALIC PROCESS of Electrodeposition provides a wide range of coatings on to most basis materials, including aluminium. It is particularly suitable for plating selected areas without stopping-off, for on-site work, and for plating assemblies or components which may not be immersed in plating solutions.

For such non-decorative purposes as building-up worn or overmachined parts, the extremely high speed of deposition and the accuracy with which deposit thickness can be controlled are most attractive features. Deposits are characterised by low stress, extremely fine grain, perfect adhesion and complete absence of porosity.

The DALIC PROCESS has received overwhelming acceptance by industry and recent installations have been made in the electronics, motor car, radio and television and armaments industries, in the Ministry of Supply, and in various research establishments.

Characteristics of Dalic Deposits

Deposit	Maximum Current density (amp./sq. ft.)	Brinell hardness of deposits	Time to deposit 0.0001 in.* (sec.)
Bismuth	1,250	50	7.6
Cadmium	6,000	40	2.5
Chromium	4,000	600	63
Cobalt	1,500	250	7.6
Copper	6,000	150	2.5
Gold	2,000	100	6.2
Indium	4,000	<1	2.5
Iron	3,000	175	10.2
Lead	5,000	20	3.8
Nickel	5,000	500	5.1
Platinum	3,000	200	17.5
Rhodium	3,000	500	70
Silver	1,250	60	5.1
Tin	5,000	1	2.5
Zinc	3,000	70	3.8

** Assuming the pad electrode employed were stationary. Since, in practice, it is moved over the surface being plated, this time should be increased by the area of the surface divided by the area of the pad.*

A practical demonstration at our laboratories will be given without obligation

Sole Licensees for the British Isles

METACHEMICAL PROCESSES LTD.

13, STRAFFORD ROAD · LONDON · W.3 · ACORN 0131/2

SITUATIONS VACANT (Cont'd.)

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

at least five years' experience in the radio industry on maintenance. Excellent wages and working conditions in modern Cold Reduction Plant. Applications, giving details of age, qualifications and experience, should be submitted to: The Supt. Labour and Wages, The Steel Company of Wales Limited (Tinplate Division), Carmarthen Road, Swansea. W 2948

THE TELECOMMUNICATIONS DIVISION of the Plessey Company requires, for work in its Laboratories at Ilford, a limited number of Senior Engineers experienced in either the electronic or electro-mechanical fields. The posts are permanent and pensionable and carry very adequate salaries. Age is not important, but the minimum qualifications are either a Degree in physics or engineering or at least five years' experience of advanced development of design work in connexion with radio communication, radar or industrial electronic equipment. Applicants should be of British birth. Each post involves the control of a team of engineers or technical assistants and complete responsibility, under the direction of a principal engineer, for the work of that team. A wide variety of interesting work is available and all the posts carry prospects of considerable advancement to able and energetic men. Write in confidence to the Personnel Manager, The Plessey Company Limited, Vicarage Lane, Ilford, Essex, giving details of qualifications and experience. Quoting reference EE/887. W 3056.

THREE ENGINEERS required for senior posts in the Apparatus Department of Telephone Manufacturing Co. Ltd., Martell Road, West Dulwich, London, S.E.21. Considerable former experience required in the development of light electrical apparatus to production standard. The positions offered require ability to give advice and service to the customer using the Company's apparatus; therefore circuit knowledge of an electronic nature is also desirable. Staff Bonus and Pension Scheme after qualifying period. Write, call or telephone Personnel Manager at above address. Gipsy Hill 2211. W 2998

VICKERS-ARMSTRONGS LIMITED, WEYBRIDGE. Guided Weapons Development. Applications are invited against the following vacancies: Senior Staff Appointments for experienced engineers with suitable B.Sc. Degrees, or equivalents, as: Project Officers, Trials Engineers, Electronic Engineers, other Technical Staff as: Senior Intermediate and Junior Draughtsmen (with H.N.C. or equivalent), Technical assistants (mechanical and electronic—with H.N.C. or equivalent), Mathematicians (with Degrees). Laboratory and skilled workshop personnel as: Laboratory Assistants (electronic, mechanical, and electrical, with practical experience), Toolmakers, Fitters, Centre Lathe Turners, Universal Millers, Universal Grinders, Slotters, etc. Applicants should be in a position to travel daily to Weybridge or make their own housing arrangements. Assistance can be given to secure individual lodging accommodation. Apply to Employment Manager, Vickers-Armstrongs Limited, Weybridge Works, Weybridge, Surrey. W 2955

TRANSFORMER DESIGNER required for development projects involving audio-frequency power transformers, pulse transformers, oil-filled units, etc. Apply stating age, qualifications and experience to the Personnel Manager (Ref. R.G.), The General Electric Co., Ltd., Brown's Lane, Allesley, Coventry. W 192

UNUSUAL opportunity occurs for Junior Electronic Engineer to join rapidly expanding organization. Interesting work concerned with the development of Electronic Instruments and allied equipment, with excellent prospects of rapid advancement for person of real ability Rivlin Instruments Ltd., 7a, Maitland Park Villas, N.W.3. W 1950

VACANCIES exist for Telecommunication Engineers in the Central Laboratories of a large manufacturing organization. Good academic qualifications with a good general knowledge of radio theory and application essential. A knowledge of radio propagation an advantage. Applications should be addressed to the Personnel Manager, Standard Telecommunication Laboratories Limited, Progress Way, Enfield, Middlesex. W 3115

VICKERS-ARMSTRONGS LTD., Crayford, Kent, have a number of vacancies in their Computer Laboratory as follows:— (1) Honours graduates to engage in research and development work on commercial electronic computing machines and devices (2) Engineers and Technicians to engage in development and design of electronic, commercial computing machines and devices. Qualifications, University degree, Higher National Certificate, or equivalent. (3) Electrical Draughtsmen to engage in the design of electronic commercial computing machines and devices. Salaries for all posts are in accordance with experience and qualifications. Application should be made in writing to the Manager, Engineering Department and Labour. W 3088

Further "Situations Vacant" advertisements appear in display style on pages 82, 90, and 101.

SITUATIONS WANTED

ENGINEER, age 34, with extensive experience in the production of lamps, valves and allied vacuum devices, seeks responsible position, where practical knowhow and ability to control labour, is of more importance than academic lustre. Box No. W 1925.

ENGINEER, 40 years. Experienced supervision installation all equipments including transmitters, and navigational aids. Buildings and constructional work. Specialist in tropical applications and deterioration problems. Survey work land/marine. Control of native labour; handling boats. Now leading electronics group abroad. Progressive change home/abroad. Box No. W 1944.

TECHNICAL WRITER and Lecturer seeks more progressive post. Considerable experience of radio and television industry. Position as Technical representative considered. Box No. W 1949.

SERVICE

CAPACITY available for design, detailing and tracing of electronic and electro-mechanical equipment. Used to Government procedure. Box No. W 1927.

PERSPEX industrial safety guards. Exhibition and display fittings, shop facia letters. Commercial, display and advertising signs, engraved, embossed and silkscreen printed in Perspex, P.V.C., etc. Olympic Plastics Ltd., Wembley Park, Middlesex. Wem. 7933. W 1955

FOR SALE

MAGSLIPS at 1/10th to 1/20th of List Prices. Huge stocks. Please state requirements. K. Logan, Grove Road, Hitchin 1744, Herts. W 1b3

MARCONI INSTRUMENTS. Valve Millivoltmeter. TF 899. Cost £43. Receiver Tester. TF 888 Cost £60. Audio Tester. TF 894. Cost £65. All the above as new to sell at half cost. Cash with order. Norton, 65 High Street, Shaftesbury, Dorset. W 1947

METALWORK. All types cabinets, chassis, racks, etc., to your own specifications. Philpott's Metal Works Ltd. (G4B1), Chapman Street, Loughborough. W 2197

SINE-COSINE RESOLVERS (3" Magslip Transmitters No. 5, AP 10861). Brand new, each in maker's tin. Offered in quantity at less than one tenth of cost. Export inquiries invited. P. B. Crawshay, 166 Pixmore Way, Letchworth, Herts. W 153

WEBB'S 1948 Radio Map of the World, new multi-colour printing with up-to-date call signs and fresh information, on heavy art paper 4s. 6d., post 6d. On linen on roller 11s. 6d., post 9d. W 102

EDUCATIONAL

CITY & GUILDS (Electrical, etc.) on "No Pass—No Fee" terms. Over 95 per cent successes. For full details of modern courses in all branches of Electrical Technology send for our 144-page handbook—Free and post free. B.I.E.T. (Dept. 337C). 29 Wright's Lane, London, W.8. W 142

FREE Brochure giving details of courses in Electrical Engineering and Electronics, covering A.M.Brit.I.R.E., City and Guilds, etc. Train with the Postal Training College operated by an Industrial Organisation. Moderate fees. E.M.I. Institutes, Postal Division, Dept. EE/29, 43, Grove Park Road, London, W.4. W 190

THE COLLEGE OF AERONAUTICS. The Board of Entry of the College invites applications from suitable candidates for the two-year course which begins in October, 1954, and ends in June, 1956. Candidates should be of graduate standard, although the possession of a Degree is not essential; a good Higher National Certificate is an acceptable standard. The college, a post graduate institution, is devoted to the study of aeronautical science and engineering. The curriculum covers the five main subjects of Aerodynamics, Aircraft Design, Aircraft Electrical Engineering, Aircraft Propulsion and Aircraft Economics and Production. Instruction in the first year is designed to provide students with a broad background of knowledge in all these subjects, with opportunity for limited specialization in two or three of them. In the second year students specialise more particularly, usually in one subject. Experiments in the air are an important part of the work, both in the first year when all students take part in them and in the second year when they are linked to the specialist work of the departments. Students who satisfactorily complete the course will receive the Diploma of the College. Further particulars and details of the procedure for application may be obtained from: The Warden, The College of Aeronautics, Cranfield, Bletchley, Bucks. W 3090

THE UNIVERSITY OF SOUTHAMPTON. Department of Electronics. The Department of Electronics gives an advanced course at Honours Degree standard in Electronics. The course is full-time for one academic year and the University grants a Diploma by examination to students who successfully complete the course. Entry qualification is a University Degree in Physics or Electrical Engineering, or its equivalent. The next course will commence in October, 1954, and application for admission should be made now to the Academic Registrar, from whom further details may be obtained. W 3054

T/V AND RADIO—A.M.Brit. I.R.E., City & Guilds, R.T.E.B. Cert, etc., on "No Pass—No Fee" terms. Over 95 per cent successes. Details of Exams., & Home Training Courses in all branches of Radio and T/V. Write for 144 page Handbook—Free. B.I.E.T. (Dept. 337G), 29 Wright's Lane, London, W.8. W 187

AGENTS

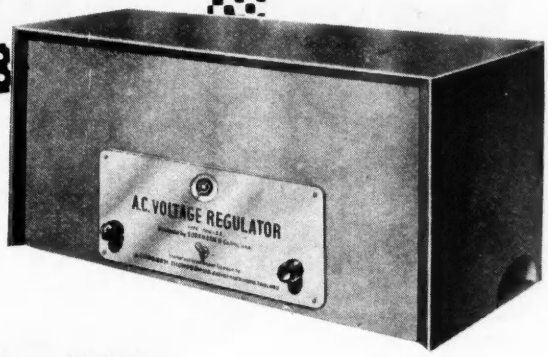
AGENTS having an extensive connexion with Research Establishments, Hospitals, etc., throughout South Wales and South West England seek to represent a reputable electronic instrument manufacturer in this territory. Capable of discussing instruments on a technical level and willing to undertake demonstrations. Box No. W 3109.

MISCELLANEOUS

A HIGH VACUUM IMPREGNATION. Unit or single or Batch Coil Impregnation service to RIC Specification 214 or individual requirements. Blickvac, 505 Lordship Lane, S.E.22. Tel. Forest Hill 7089. W 182

SORENSEN AC VOLTAGE REGULATOR

MODEL 1000-2S



OUTPUT VOLTAGE CONSTANT TO 0·1%

AGAINST INPUT VOLTAGE, INPUT FREQUENCY AND OUTPUT CURRENT

The exceptionally accurate and reliable Sorensen Regulators, already well known to Engineers, are now made in England under licence by J. Langham Thompson Ltd. Model No. 1000 2-S — an A.C. Regulator — is the first in production, and other models will be announced in due course as soon as they are available.

Descriptive literature will be gladly sent on request.

Specification

RATING	1 KVA
INPUT VOLTAGE	190-260
INPUT FREQUENCY	50 c/s±10%
OUTPUT VOLTAGE	220-240 (adjustable)
REGULATION ACCURACY	±0·1% max.
RECOVERY TIME	0·1 secs.
HARMONIC DISTORTION	3% max.
P.F. RANGE	Down to 0·7
LOAD RANGE	No load to full load

JLT GROUP

J. LANGHAM THOMPSON LIMITED

BUSHEY HEATH · HERTS

Telephone: Bushey Heath 2411 · Grams and Cables: "Tommy Watford"

5 Germanium Diodes

for the specialized equipment designer

Where small size and stability of characteristic, unaffected by repeated cycles of humidity, are of first importance choose STC diodes, which will give you complete reliability. The five types described below are available from stock, and others are in course of development.

Abridged Data at 20°C	TYPE NUMBERS				
	2X/102G	2X/103G	2X/104G	2X/105G (CV448)	2X/106G (CV425)
Peak Inverse Voltage (V)	85	30	30	100	70
Minimum Reverse Resistance (kilo-ohms)	500 (at 70V)	100 (at 20V)	100 (at 20V)	500 (at 50V)	50 (at 50V)
Maximum Forward Resistance (ohms)	500 (at 1V)	250 (at 1V)	1000 (at 1V)	333 (at 1V)	250 (at 1V)

Comprehensive data sheets may be obtained from :

Standard Telephones and Cables Limited

(Registered Office : Connaught House, Aldwych, London, W.C.2.)

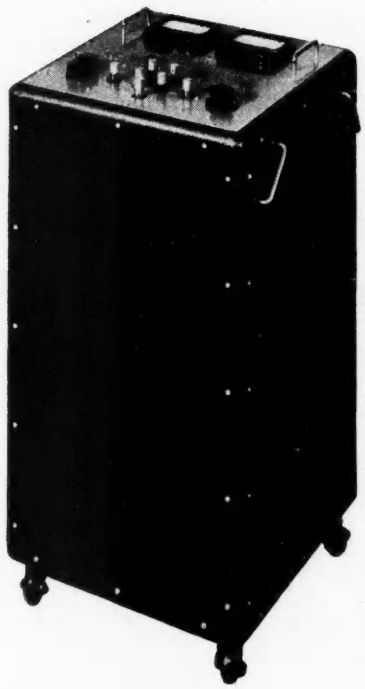
Radio Division

OAKLEIGH ROAD, NEW SOUTHGATE, LONDON, N.11

Electrical Control Instruments

By SERVOMEX

SERVOMEX is a registered trade mark



D.C. VOLTAGE STABILISER TYPE D.C.3

Output 1-30 volts D.C. Current 0-7 amps.
D.C. accuracy 25 mV.
Rectifier ripple less than 0.05% peak. (At full load)

Full details of the two instruments described above will gladly be sent on application to—

STICKY METERS?

Testing meters for stiction of the movement by the age-old method of turning a knob and hoping, is both tedious and unreliable. The SERVOMEX meter tester type MT.1 is rapid, consistent and INFALLIBLE.

SERVOMEX CONTROLS LTD., CROWBOROUGH HILL, JARVIS BROOK, SUSSEX
Telephone : Crowborough 1247

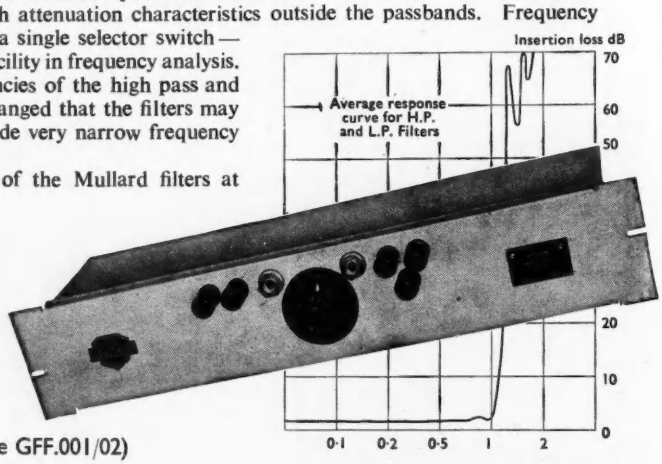
Improved high and low pass filters

TEN CUT-OFF FREQUENCIES IN ONE COMPACT PANEL

THESE Mullard variable cut-off filters, originally developed in conjunction with the British Post Office, represent a marked advance in filter technique. New design features together with the use of Ferroxcube pot cores have resulted in a valuable reduction in panel size, as well as high attenuation characteristics outside the passbands. Frequency ranges are controlled by a single selector switch — an especially important facility in frequency analysis.

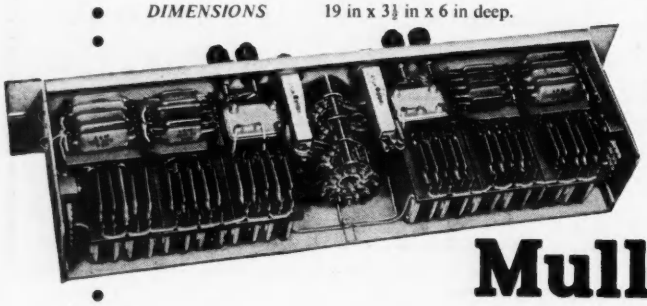
The ten cut-off frequencies of the high pass and low pass filters are so arranged that the filters may be used in pairs to provide very narrow frequency samples.

Brief technical details of the Mullard filters at present available are given here; communication engineers and research workers who may require more comprehensive information are invited to apply to the address below.



High-Pass Filters (Type GFF.001/02)

CUT-OFF FREQUENCIES (fc)	440, 660, 990, 1480, 2222, 3333, 5000, 7500, 11250, 16800 c/s selected by 10-way switch
IMPEDANCES	Input and output 600 ohms, balanced or unbalanced
STOPBAND ATTENUATION	At 0.8 x fc — 50 dB At 0.6 x fc — 60 dB
PASSBAND ATTENUATION	3dB ± 1 dB from 1.1 x fc to 20 or 25 kc/s depending on cut-off frequency (fc)
DIMENSIONS	19 in x 3½ in x 6 in deep.



Low-Pass Filters (Type GFF.001/01

CUT-OFF FREQUENCIES (fc)	400, 600, 900, 1350, 2025, 3040, 4500, 6830, 10250, 15400 c/s selected by 10-way switch
IMPEDANCES	Input and output 600 ohms, balanced or unbalanced
STOPBAND ATTENUATION	At 1.25 x fc — 50 dB At 1.35 x fc — 60 dB
PASSBAND ATTENUATION	2dB ± 1dB from 50 c/s to 0.9 x fc
DIMENSIONS	19 in x 3½ in x 6 in deep

Mullard

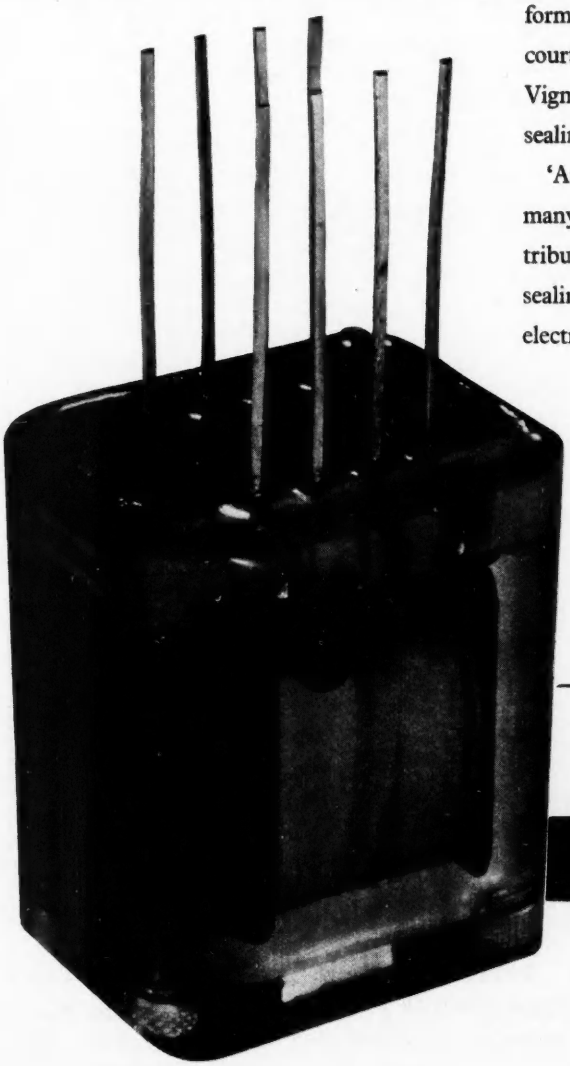
SPECIALISED ELECTRONIC EQUIPMENT

MULLARD LTD., EQUIPMENT DIVISION, CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2
(MI 433)

Sealed *with 'Araldite'*

Outstanding adhesion to metals and excellent electrical and mechanical properties combine to make 'Araldite' "the resin of choice" for sealing electrical components. Exceptionally low shrinkage on setting plus resistance to high temperatures, humidity and corrosive agents contribute further to the success of this new epoxy resin for potting or casting applications. 'Araldite' complies with the requirements stipulated for the sealing of Service equipment. Our illustration of a transformer potted in 'Araldite' is published by courtesy of the makers, Messrs. Evershed & Vignoles Ltd., who also use the same resin for sealing resistances and valve assemblies.

'Araldite' epoxies are simplifying production in many industries. Nowhere, however, is their contribution more important than in the potting and sealing of components for radio, electronics and electrical engineering generally.



THESE ARE THE NEW EPOXIES!

'Araldite' (regd.) epoxy resins are obtainable in the following forms:—

Hot and Cold setting adhesives for metals, and most other materials in common use.

Casting Resins for the electrical, mechanical and chemical engineering industries.

Surface Coating Resins for the paint industry and for the protection of metal surfaces.

Full details will be sent gladly on request

'Araldite'

casting resins

Aero Research Limited

A Ciba Company

DUXFORD, CAMBRIDGE. Telephone: Sawston 187

264-64A

Approved to ENTIRELY NEW Inter-Service Standards

A miniature range of Hunts Electrolytics approved to Inter-Service standards RCS 134 Issue 3 and RCL 134 Addendum Issue 2.

Temperature range: −30° C to +70° C max.

Please write for leaflet giving details of complete range.

Cap µF	Peak Working Volts at 70°C.	Max. R.M.S. Current at 50/c/s (mA)	Dimensions (inches) L.	D.	List Number	Inter-Service Cat. Number
TYPE L31/1. PATTERN CE4. CLASS HI						
50	25	70	1¼		JB 53AKZ	Z145512
100	25	100	1¾		JB 54KZ	Z145514
1000	25	600	3	1	JB 57KZ	Z145520
25	50	60	1¼		JB102BKZ	Z145508
50	50	100	1¾		JB103KZ	Z145513
500	50	450	3	1	JB106AKZ	Z145519
8	150	60	1¼		JB153BKZ	Z145502
16	150	90	1¾		JB154KZ	Z145505
32	150	160	1¾		JB181KZ	Z145509
8	350	75	1¾		JB403KZ	Z145503
16	350	120	1¾		JB405KZ	Z145506
32	350	225	2	1	JB407AKZ	Z145510
4	450	50	1¾		JB552KZ	Z145501
8	450	100	1¾		JB553BKZ	Z145504
16	450	175	2	1	JB554AKZ	Z145507
32	450	275	3	1	JB555AKZ	Z145511
TYPE L32/1. PATTERN CE5 CLASS HI						
3000	25	1100	4½	1⅜	KB 62KZ	Z145557
1500	50	1000	4½	1⅜	KB111KZ	Z145555
60	350	350	2	1⅜	KB430KZ	Z145552
100	350	450	3	1⅜	KB411KZ	Z145554
32	450	275	3	1	KB555BKZ	Z145551
60	450	450	3	1⅜	KB581KZ	Z145553
TYPE L32/3. PATTERN CE6. CLASS HI						
32+32	350	200	2	1⅜	KB417KZ	Z145601
60+100	350	400	4½	1⅜	KB420KZ	Z145603
60+250	350	400	4½	1¾	KB422KZ	Z145605
100+200	350	550	4½	1¾	KB423KZ	Z145606
32+32	450	300	3	1⅜	KB564AKZ	Z145602
60+100	450	550	4½	1¾	KB565KZ	Z145604

REGISTERED TRADE MARK

HUNTS CAPACITORS

THE TRADE MARK OF RELIABILITY

All units are insulated by a Suflex sleeve and dimensions must be increased by ⅛" on the length and 1/16" on the diameter to allow for this sleeve.

A. H. HUNT (Capacitors) LIMITED
WANDSWORTH · LONDON · S.W.18
Tel: BATtersea 1083-7 Est. 1901

EMOTROL

• Electronic Motor Control •

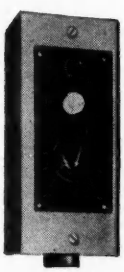
by

B T-H

Of the many notable electronic engineering achievements by BTH, the 'Emotrol' system is an outstanding contribution to meet the needs of industry for precision, wide-speed-range, motor control gear.

This system can in fact, be applied in practically any industrial process.

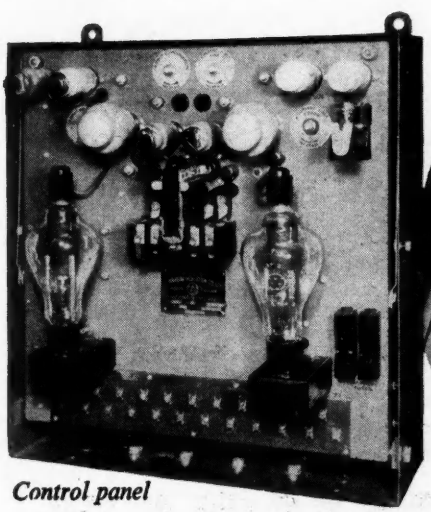
Applications include:—machine-tools, knitting machines, conveyors, printing presses, papermaking machinery, fans, reeling and tensioning drives, glass making machines, dynamometers, etc.



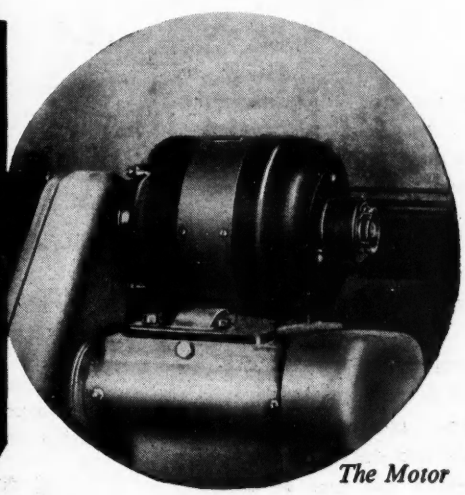
Controller

SPECIAL FEATURES:—

- Speed ranges of 100 to 1.
- Horsepower range of ·25 to 600.
- Operates from A.C. supply — static apparatus converts power to supply D.C. motor.
- Maintains precise speed at any given setting.
- Smooth stepless control throughout speed range.
- Current limit feature — gives automatic smooth acceleration and protects the electrical apparatus and the driven system from overload.
- Readily arranged to give automatic control of torque, mechanical tension, linear or rotational position, or other electrical and mechanical quantities.



Control panel



The Motor

THE

BRITISH THOMSON-HOUSTON

COMPANY LIMITED, RUGBY, ENGLAND

A4327

Member of the AEI group of companies

A.C. Discharge Detector

Designed for the non-destructible testing of insulation subject to 50 c/s alternating stresses.

For use with—

CABLES	GENERATOR INSULATIONS
CAPACITORS	INSULATORS
BUSBARS	SWITCHGEAR

TRANSFORMERS AND TRANSFORMER BUSHINGS ETC.

(*The instrument is suitable for testing to Government specifications*)

The indicator can be used with any high quality EHT transformer, providing a suitable filter is interposed between the transformer and the test specimen.

TECHNICAL FEATURES :

Tests possible up to 100KV.
Specimens of large capacity can be tested.
Specimens can be tested in situ.
The unit is easily portable.
Discharges are measured in pico-coulombs and data on probable life of specimen can thus be obtained.

A booklet entitled "An Introduction to AC Discharge Detection," which contains a summary of the leading scientific papers on this subject, will be sent on request.

HIVOLT LTD

34a, POTTERY LANE, LONDON, W.11
Tel: PARK 6955 & 5237

AVO
REGD. TRADE MARK

WIDE RANGE
Signal
GENERATOR

An inexpensive yet precision instrument designed especially to meet the exacting needs of the modern service engineer and laboratory technician. With six frequency ranges covering 50 Kc/s to 80 Mc/s, its accuracy is better than ±1% of the scale reading.

50 Kc/s-150 Kc/s	1.5 Mc/s-5.5 Mc/s
150 Kc/s-500 Kc/s	5.5 Mc/s-20 Mc/s
500 Kc/s-1.5 Mc/s	20 Mc/s-80 Mc/s

Scale sub-divisions provide more than adequate discrimination for use in television circuits. Note the starred features below, which combine to maintain a minimum of less than 1μV up to 20 Mc/s and less than 3μV between 20 Mc/s and 80 Mc/s.

★ **OUTPUT** 1
Coaxial socket for attenuated output. Force socket located totally within H.F. compartment.

MAINS TRANSFORMER 2
Marked tagboard for inputs of 100-130V and 200-260V A.C. 50/60 c/s.

★ **CAST ALUMINIUM H.F. COMPARTMENT & CHASSIS** 3
Large number of fixing holes for H.F. compartment cover ensures excellent electrical bonding and good screening.

FUSE 4
Easily accessible when replacement is necessary.

VALVE 5
Standard types run at a rating to ensure long life.

TURRET COIL SWITCHING 6
Standard "AVO" practice.

★ **ATTENUATOR SYSTEM** 7
Employs close tolerance, high stability midget carbon resistors, low reactance rotary potentiometer modified for H.F. operation with carefully designed screening.

Other features include:

ILLUMINATED SPOT RANGE SELECTOR
Gives rapid identification of operational band with intensified lighting round precise frequency. Fine hair line gives close discrimination, particularly on high frequencies.

STOPS
Separate stops prevent turning of dial with respect to condenser.

★**MAINS FILTER SYSTEM**
This is screened from main electrical assembly.

BUSHING PLATES
provide additional rigidity for rotary controls.

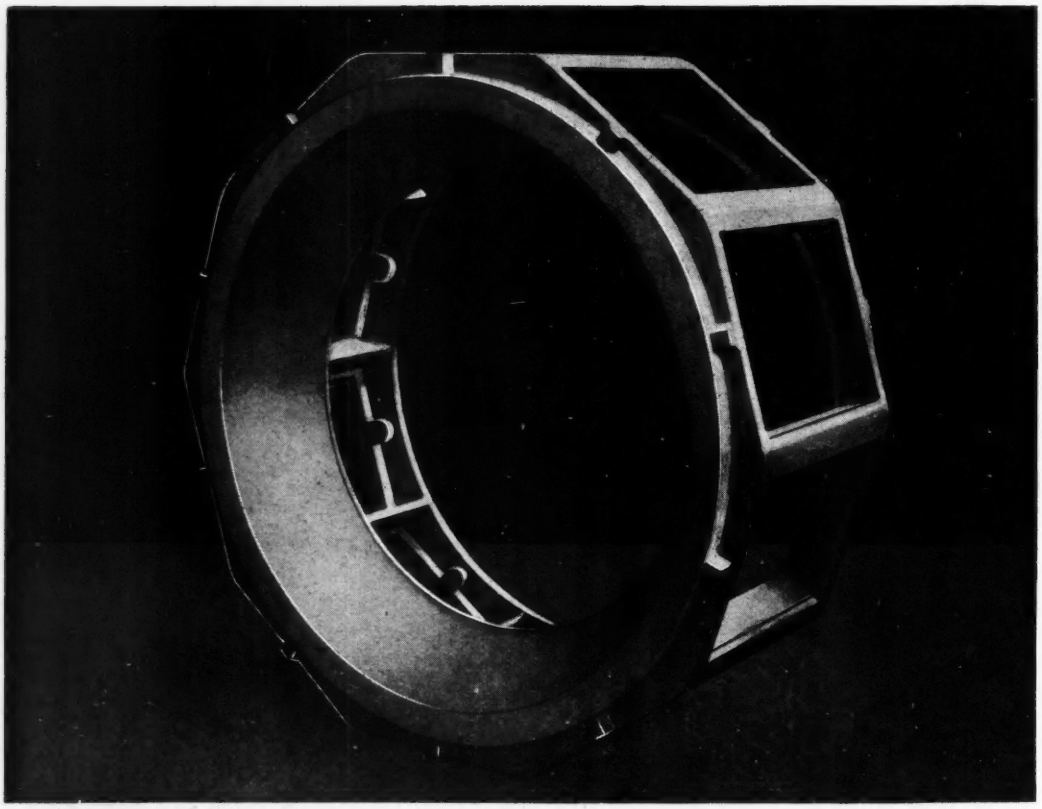
SLOW MOTION DRIVE
substantially free from backlash.

MAINS MODEL 100-130V and 200-260V A.C. 50-60 c/s £38
or BATTERY MODEL £30

Sole Proprietors and Manufacturers

The AUTOMATIC COIL WINDER & ELECTRICAL EQUIPMENT CO. Ltd.
WINDER HOUSE • DOUGLAS STREET • LONDON • S.W.1 *Telephone:* VICTORIA 3404/9

S.G.2



Aluminium Alloy 3L33
Sand Casting
Weight 435 lb.

C.&L.HILL LTD

Manufacturers of

Non-Ferrous Sand Castings, Brass, Naval Brass, Brazing Metal, Gunmetal, Phosphor Bronze, Aluminium Bronze, High Tensile Manganese Bronze, High Conductivity Copper, "Hilchil" Chill Cast Phosphor Bronze Bars, Cored and Solid. Sand Castings in all Aluminium Alloys, including Heat-treated Alloys, Aluminium Alloy Gravity Die Castings.

Wood and Metal Pattern Shop. Fully Approved Laboratory and Test House with Inspection Organization. Facilities for Radiology.
Specialists in Development and Quantity Production of Castings for Radar.

We solicit your enquiries for
SHELL MOULDED CASTINGS
in all non-ferrous Alloys, including Aluminium

Stringes Lane, Willenhall, S. Staffs.

Tel: Willenhall 227 (4 lines) ***Grams: Hill 227 Willenhall***
Branch Works: **Wednesfield Road, Willenhall**
Both our Foundries are available for Prototype Work

MEMBER OF THE OWEN ORGANISATION

WhiteAd 2738

Photograph by courtesy of Handley Page Ltd.

with GOODMANS VIBRATORS

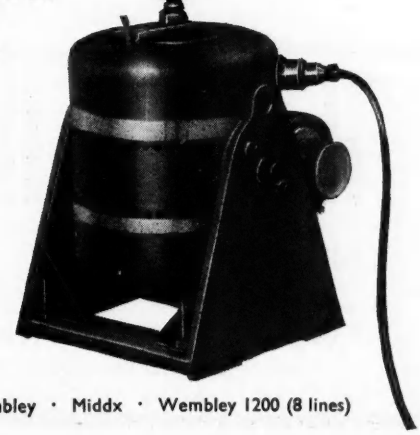
The flight characteristics of a newly designed aeroplane are the subject of lengthy calculations before the first prototype is built. Whilst the mathematical calculations are themselves accurate, they are based, as in all design work, on several assumptions which have to be verified by a series of pre-flight tests.

One of these essential investigations is the Ground Resonance test, the purpose of which is to determine the various complex modes of vibration of the airframe structure. The frequency of the mode and the dynamic response at remote parts of the aircraft must be accurately determined. The information obtained together with the aerodynamic derivatives is used in predicting the critical ' flutter ' speed of the aircraft. The illustration shows one of the two Goodmans Model 8/600 Vibration Generators which were used to excite the Handley Page " Victor " for this very important test.

For wide frequency range vibration testing and dynamic response investigations, Goodmans Vibration Generators are an obvious choice. These units require no field excitation and provide a faithful reproduction of the input wave form. Industrial applications of controlled vibration are continually increasing ; maybe it can serve you—in which case our unique experience is at your service.

The range includes models from the 8/600 shown, developing a force of ± 300 lb., to the midget model, with a force of ± 2 lb., for optical cell research and hairspring torque testing, etc.

Just another of the wide applications of Goodmans Vibration Generators. Full technical data available from Vibration Division E.

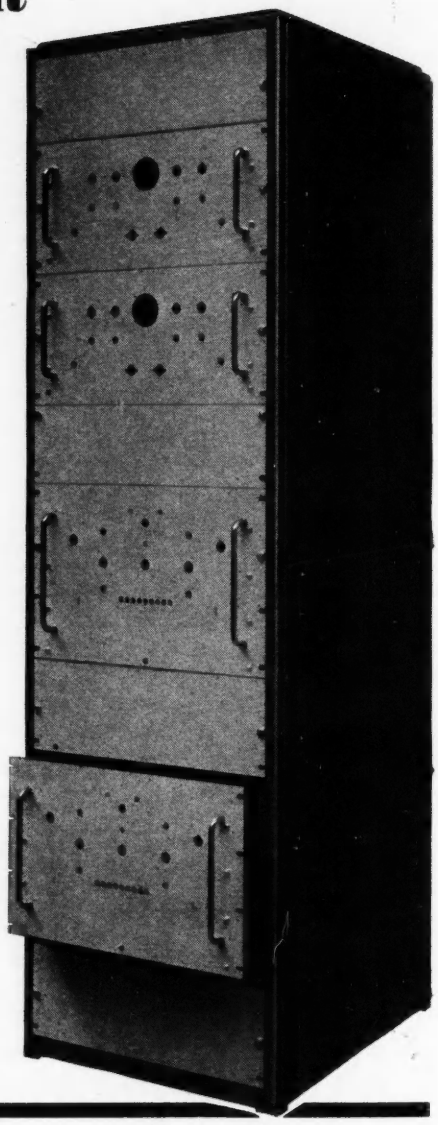


GOODMANS INDUSTRIES LIMITED, Axiom Works · Wembley · Middx · Wembley 1200 (8 lines)
GD

Electronic Instrument Cabinets, Racks and Cases

Your delicate and expensive Electronic Equipment deserves worthy housing. H. & H. Cabinets and Racks add, to unique design and precision craftsmanship, the crowning merit of superb finish. Specialists in the production of precision sheet metal work, for many years, we are admirably equipped to provide to your own specification Cabinets of a high standard of craftsmanship throughout at reasonable prices.

Our Design and Development Staff is always at your disposal. May we serve you ?



H.H.130
Overall height 68½"
" width 20¾"
" depth 24"

We also manufacture precision components to users' designs : All types of Valve Screens, Coil Cans, Chassis, Panels, Condenser Mountings, Valve Mountings, Loud Speaker Chassis, and pressings and sub-assemblies in any metal.

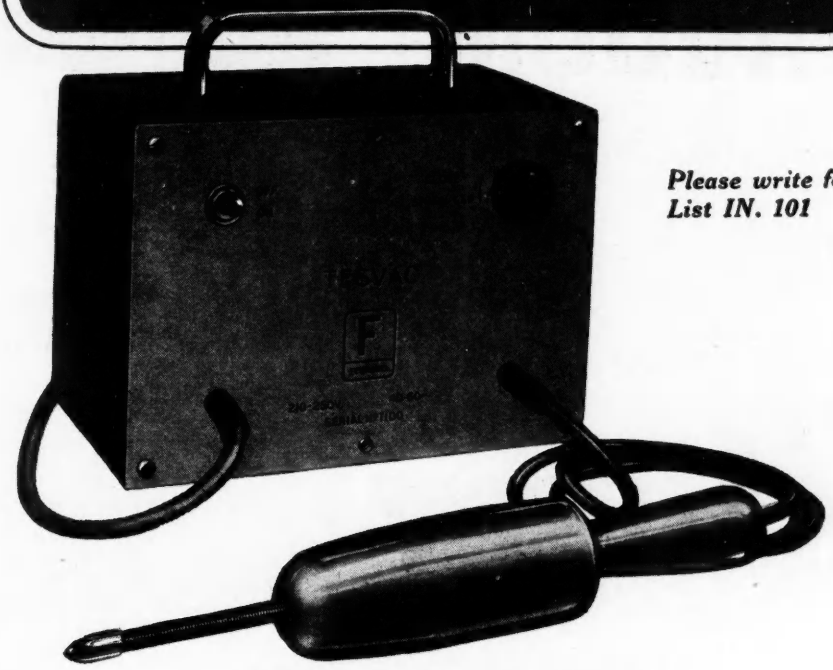
Hassett & Harper Ltd

REGENT PLACE · BIRMINGHAM · 1
Tel : CENtral 6418 (4 lines)

LONDON : 140 PARK LANE · W·1
Tel : MAYfair 9651 (3 lines)

CONTRACTORS TO GOVERNMENT DEPARTMENTS

FERRANTI
'TESVAC'
High Frequency Vacuum Tester



Please write for List IN. 101

" TESVAC " Registered Trade Mark

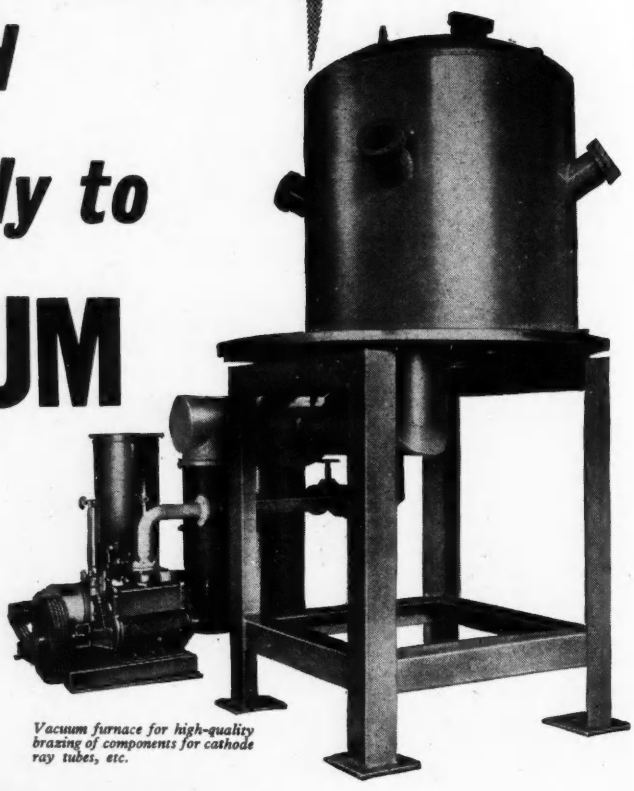
simple and safe to use . . .

- High output frequency (approx. 4 megacycles per second) gives perfect safety and more efficient energy transmission through glass walls.
- Output voltage approx. 30kV max.
- Exploring electrode very light and easy to handle.
- Components readily accessible and interchangeable.

FERRANTI

FERRANTI LTD · MOSTON · MANCHESTER 10
Head Office and Works : HOLLINWOOD · LANCASHIRE
London Office : **KERN HOUSE · 36 KINGSWAY · W.C.2**
FI 118

The trend is strongly to VACUUM with Kinney VACUUM PUMPS



Vacuum furnace for high-quality brazing of components for cathode ray tubes, etc.

New products, improved products, reduced costs daily build up the impulse to **production** processing with the aid of Kinney High Vacuum Pumps. Large scale manufacture of electric lamps and cathode ray tubes, lens coating, drug production, metal sintering, typify innumerable applications which 'go one better' on existing products and make profitable propositions of other, quite new ones.

GENERAL ENGINEERING CO (RADCLIFFE) LTD

GENERAL ENGINEERING CO. (RADCLIFFE) LTD., Station Works, Bury Road, Radcliffe

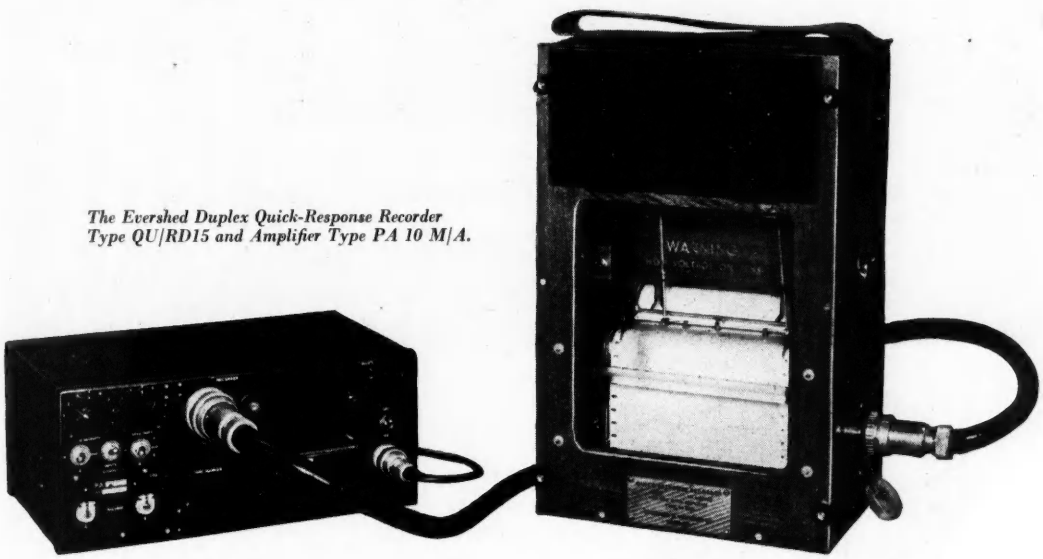
Telephone RADcliffe 2291/3 (3 lines) London Office: 3rd Floor, 9 Victoria Street, London, S.W.1. Tel.: ABBey 5278

HIGH INPUT IMPEDANCE

coupled with rapid response

THE EVERSHED

QUICK RESPONSE RECORDER



The Evershed Duplex Quick-Response Recorder Type QU/RD15 and Amplifier Type PA 10 M/A.

Please visit us at STAND No. 66 Association of Supervising Electrical Engineers' Exhibition.

—

EARLS COURT MARCH 16th—20th

The Evershed Quick Response Recorder is servo operated, and works in conjunction with an electronic amplifier. Recorder input is opposed by the feed back voltage from a resetting potentiometer controlled by position of the pen. The error (the voltage difference) drives the pen movement until the feed back voltage balances the input. Maximum sensitivity, with centre zero, plus/minus 4 volts full scale deflection.

The instrument will record sine wave voltages up to 15 cycles per second with amplitude error not exceeding 15% at a peak to peak amplitude of 1½ inches. At smaller amplitudes the frequency response will be higher.

Full details are given in Publication E.E. PL. 33

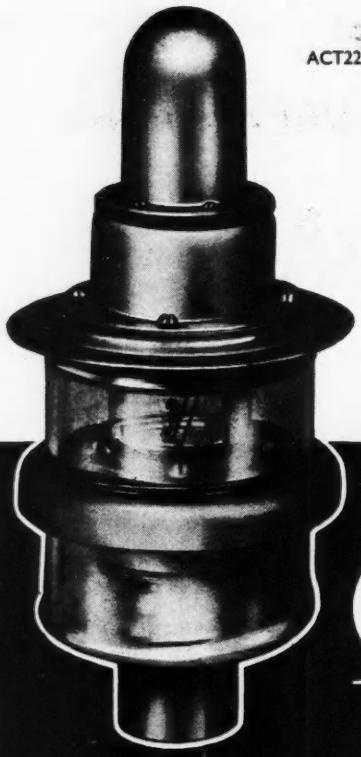
EVERSHED

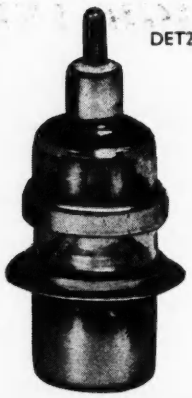
EVERSHED AND VIGNOLES LIMITED

ACTON LANE WORKS · CHISWICK · LONDON · W.4

Telephone: Chiswick 3670 · Telegrams: Megger, Chisk, London · Cables: Megger, London

6/120

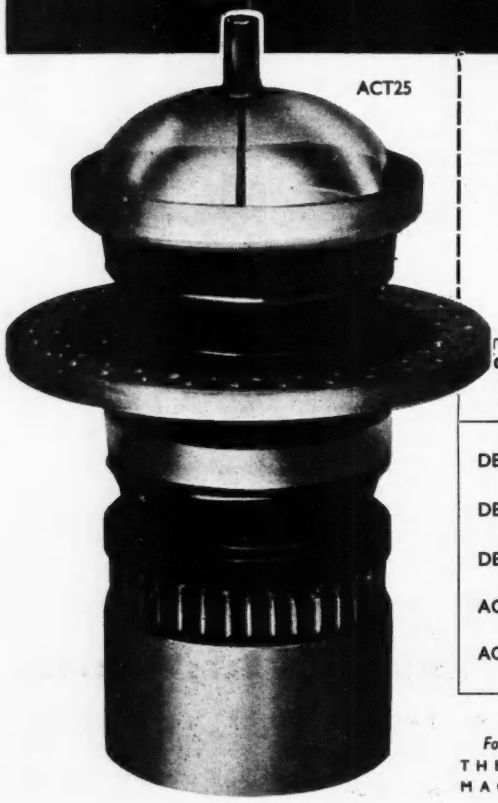




DISC SEAL

Osram U.H.F.

TRANSMITTING TRIODES



This range of common grid disc seal triodes is of outstanding interest to all designers of low and medium power transmitting equipment.
The valves are in production both as services preferred and commercial types. The advice of our engineers, backed by an unrivalled experience in this highly specialised field, is freely available for the solution of individual application problems.

OSRAM TYPE No.	SERVICES No.	ANODE DISSIPATION	MAX. USEFUL FREQUENCY (APPROX.)	TYPICAL PERFORMANCE AT 1000 Mc/s	
				OSCILLATOR EFFICIENCY	AMPLIFIER GAIN
DET22	CV273	10W	3500 Mc/s	33%	—
DET23	CV354	10W	2500 Mc/s	—	15db (Noise factor-12db)
DET24	CV397	20W	2000 Mc/s	33%	10db
ACT22	CV257	75W	1250 Mc/s	40%	8db
ACT25	CV436	400W	1100 Mc/s	30%	3db

ACT22 and ACT25 are forced-air cooled.

For further information write to: The Osram Valve and Electronics Dept.,
THE GENERAL ELECTRIC COMPANY LIMITED
MAGNET HOUSE, KINGSWAY, LONDON W.C.2

OC10 OC11 OC12 — 3 JUNCTION TRANSISTORS for circuit experiments

Three types of junction transistor, the Mullard OC10, OC11 and OC12 are now available for circuit experiments.

In the past, the lack of supplies has prevented circuit designers in this country from gaining direct experience of junction transistors in their own laboratories. Now, however, the availability of the first junction types invites practical investigation into their many possible applications.

As junction transistors provide no current gain when connected with grounded base, they are more usually employed in grounded emitter circuits, where they function well as A.F. amplifiers. In both amplifier and oscillator circuits these transistors will operate with supply voltages as low as 1.5 V and with current consumptions of the same remarkably low order.

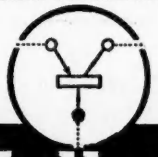
The OC11 is a general-purpose amplifier, while the OC12 is intended for operation in an output stage, although it can, of course, be used otherwise. A low-noise version of the OC11 is provided by the OC10, a special transistor for early stages in high-gain amplifiers.

Junction transistor type		OC10	OC11	OC12
Max. D.C. negative collector-to-emitter voltage	(V)	4	4	4
Typical D.C collector voltage	(V)	2	2	2
Typical collector current	(mA)	−0.5	−0.5	−2
Current amplification factor (α') with grounded emitter		17	17	30
Output resistance with infinite A.C. source impedance (grounded base)	(KΩ)	700	700	500
Special low-noise characteristics		★	—	—

★ Superior type for these characteristics.

Information on these junction transistors and the point-contact types in the Mullard range of semi-conducting devices will be gladly supplied by the Industrial Technical Service Department at the address below.

● The OC10, OC11 and OC12 are readily available for experimental purposes at a price comparable with that of mains subminiature valves.



Mullard

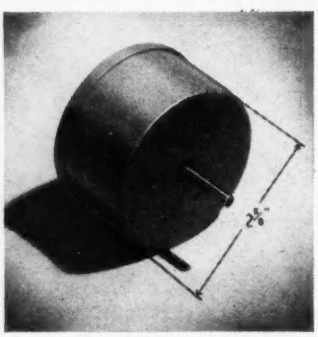
MULLARD LIMITED, COMMUNICATIONS & INDUSTRIAL VALVE DEPT., CENTURY HOUSE, SHAFTESBURY AVE., LONDON, W.C.2

MVT152

TOROIDAL POTENTIOMETERS

If you would like full details of our range of Toroidal High Precision, Helical and Heavy Duty Ceramic Potentiometers, send for our newly-published Catalogue No. 102.

Ceramic Insulation only — and approved for Tropical conditions. Complete Ceramic Rings for strength. Approved by all Government Departments. Also precision Toroidal-wound Potentiometers (including 360° of winding with up to eight tapping points) and Helical wound Potentiometers of 3600° of winding. All are available with sealed spindles and glass or ceramic terminal seats.



PRECISION POTENTIOMETERS
Type B (High Linear Accuracy)
SPECIFICATIONS

Rating—3 watts.
Resistance Range—500 ohms to 100,000 ohms.
Winding—Nickel/Copper and Nickel/Chrome Wires.
Effective Angle of Winding—270°–355° as specified.
Overall Resistance Tolerance—±5% or as specified.
Linear Accuracy—Within 0.1% or as specified.
Angle of Rotation—Continuous rotation—no stops.
Tappings—Special to requirements.

Thanks to extensive re-organisation, we can now give good delivery of all types of potentiometers

P · X · FOX LTD · HAWKSWORTH RD · HORSFORTH · YORKSHIRE
Telephone: Horsforth 2831/2 *Telegrams: Toroidal, Leeds*

P·X·F

ndh2945

SenTerCel H.T. rectifiers *from* 125V 30mA *to* 250V 325mA

Specially designed for use in domestic Radio & Television receivers, these miniature rectifier stacks have an established position with manufacturers to whom reliability, small dimensions and low costs are important.

FEATURES

- Instant starting — no warming-up period
- Unlimited instantaneous overload
- No limit to size of reservoir capacitor
- Simple mounting—no valve holder
- Withstand overloads such as charging current of de-formed electrolytic capacitors
- Low heat dissipation
- Practically indestructible in service
- Simple wiring—two connectors only
- Small size . . . low weight
- Low cost

TYPE	RM0	RM1	RM2	RM3	RM4	*RM5
Maximum ambient temperature Maximum output current (mean) Maximum input voltage (r.m.s.) Maximum peak inverse voltage Max. instantaneous peak current Weight	35°C 55°C 30mA 15mA 125V 350V Unlimited 0.82 oz.	35°C 55°C 60mA 30mA 125V 350V Unlimited 1 oz.	35°C 55°C 100mA 60mA 125V 350V Unlimited 1.4 oz.	35°C 55°C 120mA 90mA 125V 350V Unlimited 2 oz.	35°C 40°C 275mA 250mA 250V 700V Unlimited 4.5 oz.	35°C 40°C 325mA 300mA 250V 700 V Unlimited 4·75 oz.

*For use in voltage doubler circuits the peak inverse and maximum input voltages are halved, current output being as for half wave operation.

SELENIUM
SenTerCel
RECTIFIERS

Standard Telephones and Cables Limited

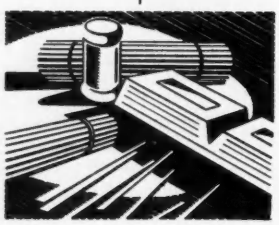
Registered Office: Connaught House, Aldwych, London, W.C.2

RECTIFIER DIVISION: Warwick Road, Boreham Wood, Hertfordshire. *Telephone: Elstree 2401*

Photograph by courtesy of Gresham Transformers Ltd.

Where solder does an *important* job . . .

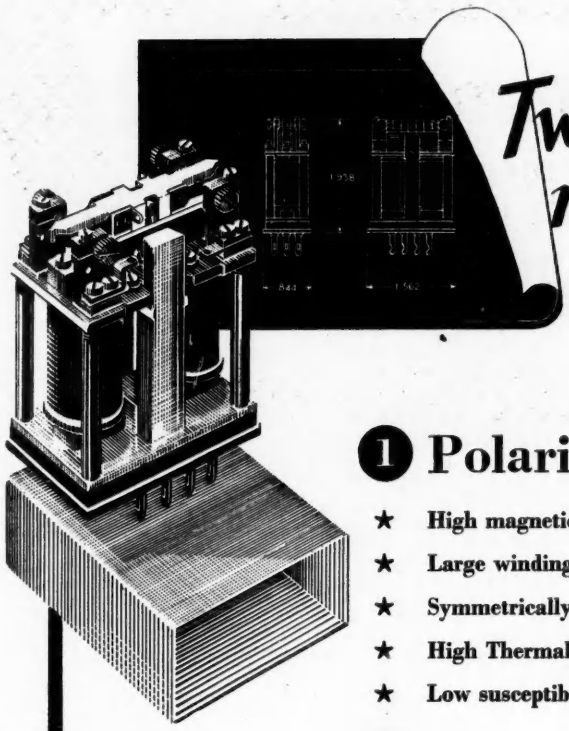
the electronic engineer relies on Enthoven products. Here a transformer is safely sealed in its case with Enthoven solid solder wire, just one of hundreds of different finishing operations successfully completed with Enthoven solders. Enthoven Tinmans, Blowpipe, Ingot, and Solid Wire Solders are supplied to B.S. 219 — 1949 and to customers' specifications. "Telecene" liquid activated rosin based flux made by Enthoven is the ideal fluxing medium for pre-tinning and dip soldering.



Our technical advisers and laboratory staff are available for free consultation. Technical data, descriptive literature and samples will be gladly sent on request.

ENTHOVEN SOLDER PRODUCTS

ENTHOVEN SOLDERS LTD., 89 UPPER THAMES ST., LONDON, E.C.4 Phone : MANsion House 4533 Telegrams: ENTHOVEN PHONE LONDON E.3426



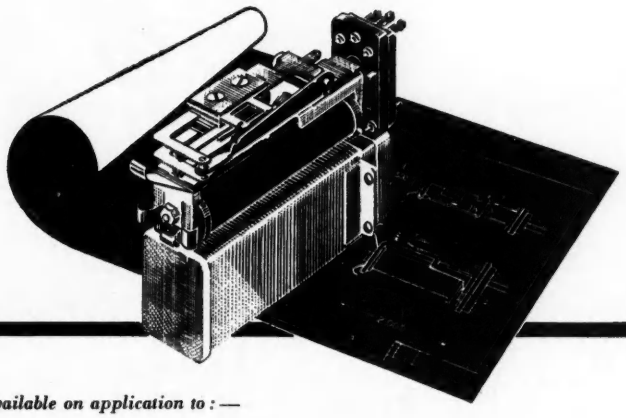
Two NEW miniature Relays

1 Polarised Relay

- ★ High magnetic sensitivity
- ★ Large winding space · High copper efficiency
- ★ Symmetrically balanced movement
- ★ High Thermal and Shock stability
- ★ Low susceptibility to magnetic interference

2 Type 1A Relay

- ★ Exceptionally high sensitivity
- ★ Balanced movement
- ★ High Thermal and Shock stability
- ★ Hermetically sealed



TELEPHONES Ericsson LIMITED

Catalogue available on application to : —

Head Office : 22 LINCOLN'S INN FIELDS LONDON WC2 *Tel: HOL. 6936*

E.17

TRANSDUCERS

for the measurement of STEADY, FLUCTUATING OR SURGE PRESSURES

(Gauge or Differential)

FOR STEADY OR SLOWLY FLUCTUATING PRESSURES

TYPE No. 548
0—5 p.s.i. to 0—4,000 p.s.i.
(as illustrated)

Comprising a Bourdon tube or bellows operating a precision potentiometer. These transducers produce a voltage output directly proportional to pressure.

FOR STEADY, FLUCTUATING OR SURGE PRESSURES

TYPE No. 522
0—25 p.s.i. to 0—2,500 p.s.i.

Pressure is applied to a diaphragm which is caused to change the inductance of an iron cored circuit. This change of inductance can then be used either to create out-of-balance in a bridge or to frequency modulate an oscillator.

TYPE No. 449
0—10 p.s.i. to 0—1,000 p.s.i.

TYPE No. 448
0—250 p.s.i. to 0—50,000 p.s.i.

Comprising a 4-arm strain gauge compensated bridge. These transducers produce a voltage output (m.V.) directly proportional to the applied pressure.

J. LANGHAM THOMPSON LIMITED

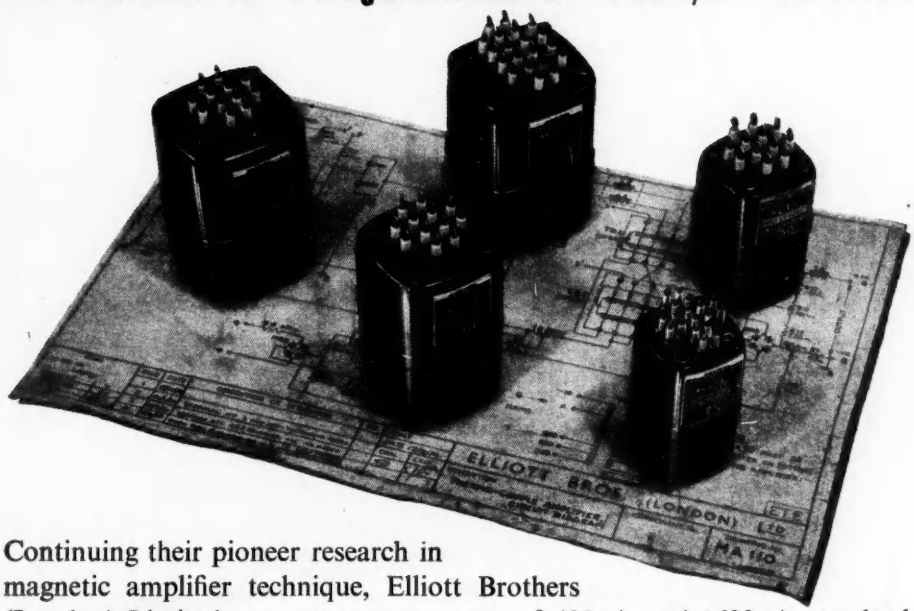
BUSHEY HEATH · HERTS

Telephone: Bushey Heath 2411 · 'Grams & Cables: "Tommy Watford"

ELLIOTT

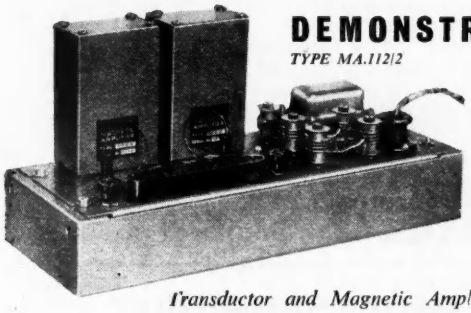
Standard Transductors

FOR OPERATION AT FREQUENCIES OF 400 c/s AND 1600 c/s



Continuing their pioneer research in magnetic amplifier technique, Elliott Brothers (London) Limited announce a new range of 400 c/s and 1600 c/s standard transductors developed to specifications of the Royal Aircraft Establishment.

- *Hermetic sealing.*
- *Push-pull input transductor units.*
- *Output transductors rated up to 80 watts.*
- *Decreased time constants.*
- *Reduced dimensions and weights.*
- *Exceptional life without maintenance.*
- *Extreme ruggedness.*
- *Multiple isolated inputs.*
- *Summation of inputs.*
- *Stable d.c. amplification.*



DEMONSTRATION MAGNETIC AMPLIFIER

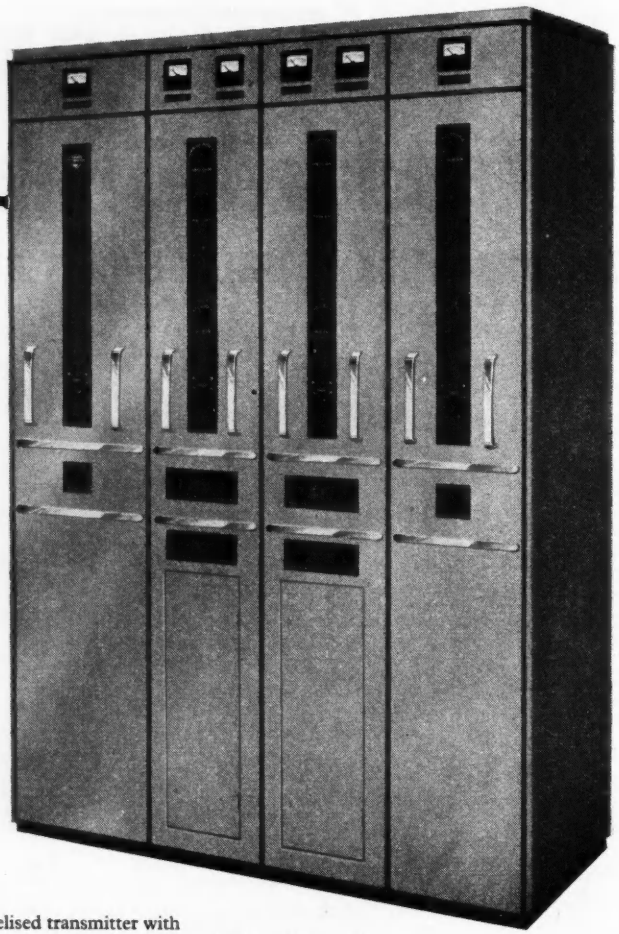
TYPE MA.112/2

Capable of being set up rapidly in various circuit forms. this flexible general purpose instrument is specially designed to enable electronic engineers and students to investigate the characteristics and applications of magnetic amplifiers. For use in research establishments, development laboratories, technical schools and colleges. Price £40 6s. 0d.

Transductor and Magnetic Amplifier loose-leaf data book and data sheets on Standard Magnetic Amplifiers available from ELLIOTTRONICS Division.

ELLIOTT BROTHERS (LONDON) LTD., CENTURY WORKS, LEWISHAM, LONDON, S.E.13. TIDEWAY 3232

1 kW Channelised Transmitter



THE GFT.560 is a 1kW channelised transmitter with a frequency range of 1.5—30 Mc/s. It consists of three basic cabinets—r.f. unit, modulator unit, and power supply unit—combinations of which can be used to provide multi-frequency working as well as a number of different types of emission. The wave change facilities of the transmitter are both rapid and reliable—a valuable asset when the operating frequency is changed many times each day.

The GFT.560 is fully tropicalised, and its unit construction facilitates future expansion of the initial installation, should the need arise.

For use in conjunction with the GFT.560 there are ancillary units that enable the transmitter to be remotely controlled over a two wire telephone circuit: operational adjustments are dialled to the transmitter.

The versatility and reliability of this new Mullard transmitter make it particularly suitable for h.f. en-route, ground-to-air services and point-to-point communication networks. A team of Mullard communication engineers is available to advise on the use of the GFT.560 in such applications. They will also assist in planning complete communication systems, if required.

ABRIDGED DATA

Frequency Range *1.5 — 30 Mc/s*
Frequency Stability *To Atlantic City, 1947, standards*
Power Output *1 kW*
Types of Emission *c.w., m.c.w., telephony, frequency shift, single and independent sideband. (A1, A2, A3, F1, A3a and A3b)*
Output Impedance *600 ohms balanced twin feeder*
Power Supply *400V, 50-60 c/s, 3-phase*

Mullard

SPECIALISED ELECTRONIC EQUIPMENT

MULLARD LTD · EQUIPMENT DIVISION · CENTURY HOUSE · SHAFTESBURY AVENUE · WC2
(MI434)

ANNOUNCING

THREE NEW 'CINTEL' INSTRUMENTS

SIGNAL LEVEL METER

A dual purpose instrument for use as a general laboratory amplifier or sensitive valve voltmeter. Frequency range 20 c/s to 100 Kc/s. . Gain 85 db.

INCREMENTAL INDUCTANCE BRIDGE

Designed to measure the inductance of iron cored chokes with d.c. flowing. Inductance range 0 to 1000 H. Superimposed d.c. continuously variable from 0 to 1 amp.

AUTOMATIC FREQUENCY MONITOR (20 Mc/s.)

An extension of the well known range of 'Cintel' monitors, this new instrument will measure any frequency in the range 10 c/s to 20 Mc/s and present the answer in decimal notation on 8 panel mounted meters.

These new instruments together with the redesigned Flying-Spot Microscope MK II will be on view for the first time on STAND 38 at the PHYSICAL SOCIETY EXHIBITION. 8th-13th April Inc.

CINEMA-TELEVISION LIMITED

A Company within the J. Arthur Rank Organisation

WORSLEY BRIDGE ROAD · LONDON · SE26

Telephone HITher Green 4600

SALES AND SERVICING AGENTS

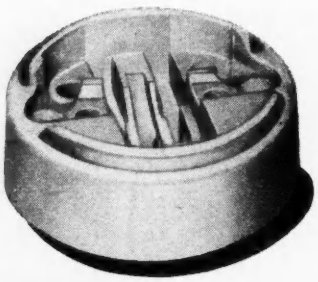
F. C. Robinson & Partners Ltd., 287 Deansgate, Manchester, 3

Hawnt & Co. Ltd., 59 Moor St. Birmingham, 4

Atkins, Robertson & Whiteford Ltd., 100 Torrisdale Street, Glasgow, S.2

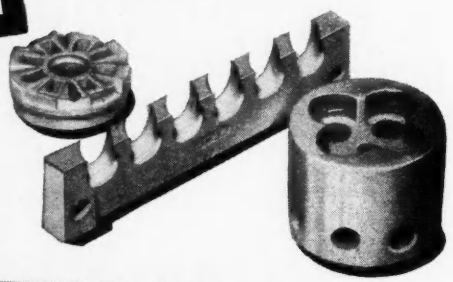
Bullers

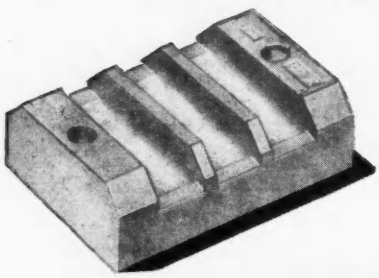
CERAMICS FOR INDUSTRY

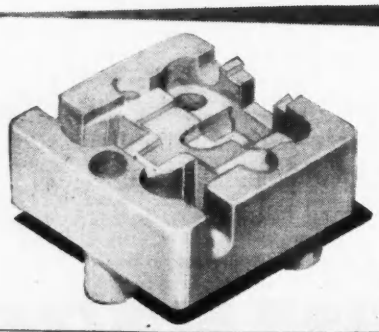


High quality material and dimensional precision are attributes of Bullers die-pressed products.

Prompt delivery at competitive prices.







BL10A

We specialise in the manufacture of

PORCELAIN
for general insulation

REFRACTORIES
for high temperature insulation

FREQUELEX
for high frequency insulation

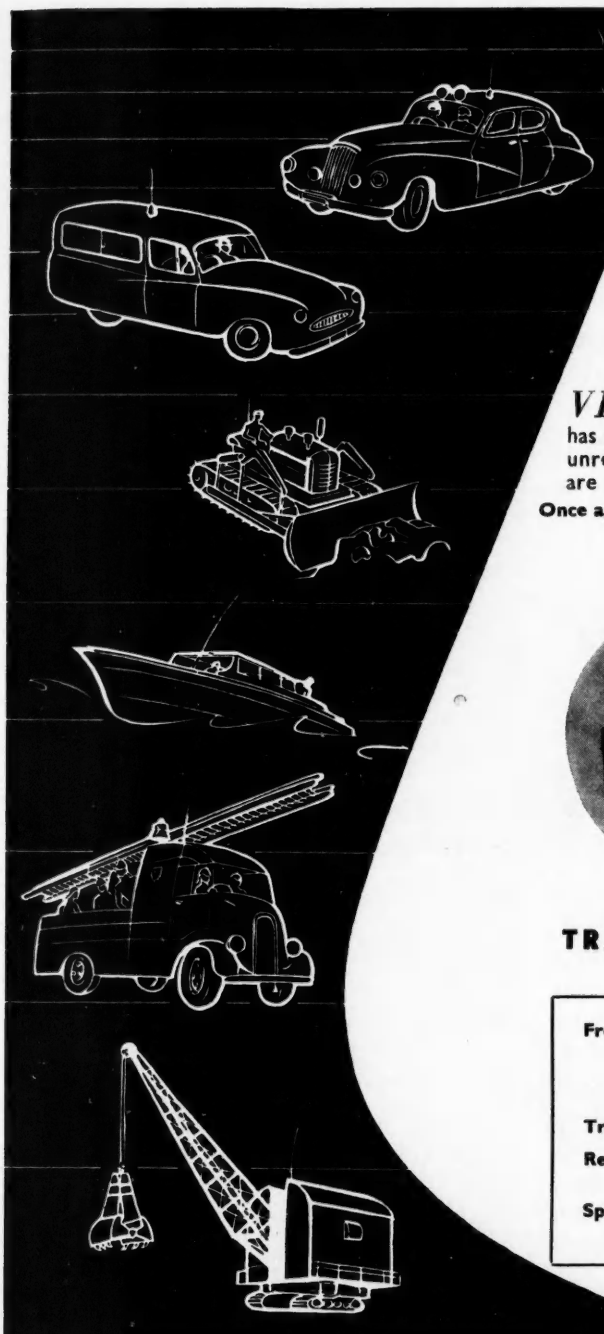
PERMALEX & TEMPLEX
for capacitors

BULLERS LIMITED

Porcelain Works :
MILTON,
STOKE-ON-TRENT
Stoke-on-Trent 5164

Sales Office :
6, LAURENCE POUNTNEY HILL,
LONDON, E.C.4
MANsion House 9971

Iron Works :
TIPTON,
STAFFORDSHIRE
Tipton 1691



B.C.C.

MOBILE EQUIPMENT

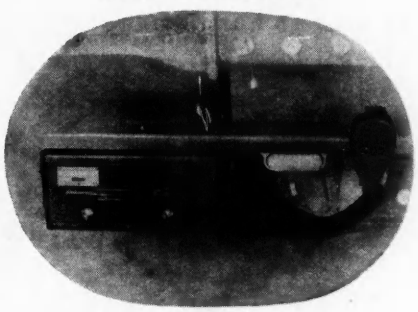
combines the unmatched performance and reliability with ease of maintenance and simplicity of operation.

VERSATILE IN USE

has many applications where central control, unrestricted mobility and immediate action are important.

Once again B.C.C. sets the standard for reliability and efficiency.

WE PRESENT



THE NEW VHF TRANSMITTER RECEIVER TYPE 68

Frequency Ranges	**L** 75—100 Mc/s. **LH** 100—135 Mc/s. **H** 115—156 Mc/s. **HH** 156—186 Mc/s.
Transmitter Power Output :	5 watts
Receiver Sensitivity :	1 microvolt for 12 db.
Spurious Response :	Better than —80 db.

BCC BRITISH COMMUNICATIONS CORPORATION LIMITED

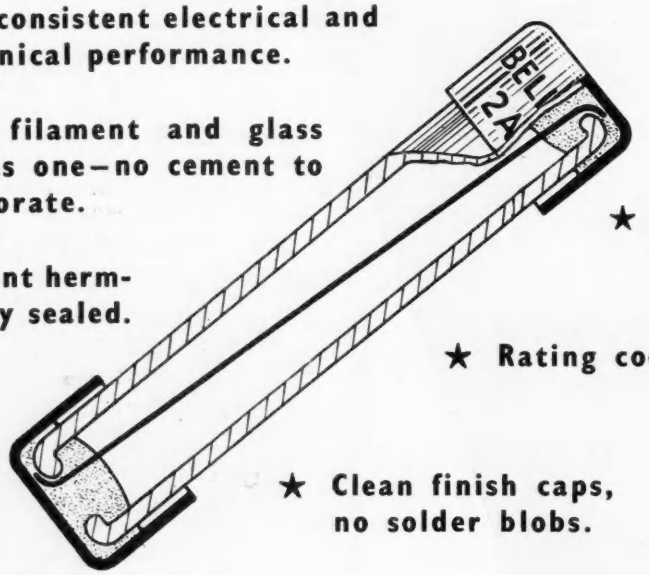
Second Way, Exhibition Grounds, Wembley, Middlesex. *Telephone : Wembley 1212*

A Mechanical and Electrical Achievement in Fuse-Link Construction

★ More consistent electrical and mechanical performance.

★ Caps, filament and glass held as one—no cement to deteriorate.

★ Filament hermetically sealed.



★ Caps permanently fixed.

★ Rating coded on caps.

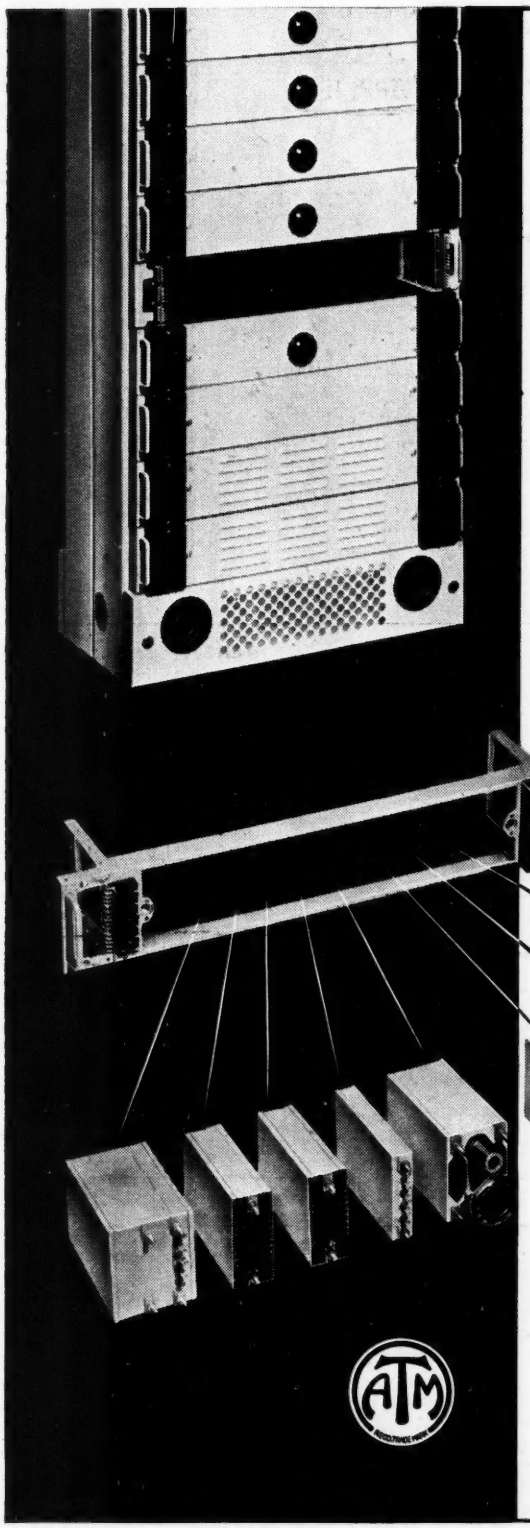
★ Clean finish caps, no solder blobs.

The L.1055 is available in ratings from 60 mA to 25 A but at present this new construction applies only to ratings of 500 mA and over. It is hoped to include the lower ratings later, but in the meantime, industry will be supplied with our original design in which we have always minimised the problems that "all-in-one" construction obviates.

Caps that come loose are things of the past; they are now locked to the glass by a unique internal soldering technique, which bonds caps, filament and glass into one unit. The glass has to break before the caps will move, and as caps are coded, the risk of random replacement by wrong ratings is obviated. Standard Size $1\frac{1}{4}'' \times \frac{1}{4}''$ dia.

Please write for catalogue P.347/E.E.

BELLING & LEE LTD
GREAT CAMBRIDGE ROAD, ENFIELD, MIDDX., ENGLAND



Designed for Continuous Service

ATE/TMC Transmission equipment is designed to offer an operating administration the maximum facility in the performance of maintenance routines. Jack-in panel frames fitted with quickly detachable functional units ensure the most rapid form of servicing yet devised. You are invited to apply for a copy of "Unit Construction Practice" which describes the technique employed.

AUTOMATIC TELEPHONE & ELECTRIC CO. LTD.

Radio and Transmission Division, Strowger House, Arundel Street, London, W.C.2. Telephone: TEMple Bar 9262. Cablegrams: Strowgerex London. Manufacturers:—AUTOMATIC TELEPHONE & ELECTRIC CO. LTD., Liverpool and London. TELEPHONE MANUFACTURING CO. LTD., St. Mary Cray, Kent.

AT 8521-BX 105

ALL-POWER
REGULATED POWER SUPPLIES

SERIES 500

An entirely new range of units, designed for the highest possible performance and overall efficiency.

Now in large scale production and available for prompt delivery.

Model 501
(fitted with end frames)

ABRIDGED DATA
(Further information on request)

	Data	Model 501	Model 502	Model 503	Model 504	Model 505
Main +VE Stabilizer	Output	200-500V 250mA	200-500V 250mA	0-500V 250mA	0-500V 250mA	0-500V 150mA
	Number of Ranges	2	2	4	4	1
	Voltage Stabilization	±0.02%	±0.002%	±0.1%	±0.002%	±0.1%
	Effective Output Resistance (max.)	0.2 Ω	0.02 Ω	0.5 Ω	0.02 Ω	0.5 Ω
	Output Ripple (rms. max.)	2mV	1mV	3mV	1mV	3mV
−VE Supply Stabilizer	Outputs	—	—	250V 25mA 0—250V 1mA	250V 25mA 0—250V 1mA	250V 25mA 0—250V 1mA
	Voltage Stabilization	—	—	±0.05%	±0.002%	±0.05%
	Output Resistance (max.)	—	—	1 Ω	0.01 Ω	1 Ω
	Output Ripple (rms. max.)	—	—	2mV	1mV	2mV
Unstabilized +VE H.T. Supply 250mA max.		470V 630V	470V 630V	320V 470V 630V	320V 470V 630V	630V
Unstabilized A.C. Supply		6.3V 10A	6.3V 10A	6.3V 10A	6.3V 10A	6.3V 10A
Price		**£70**	**£91**	**£81**	**£99**	**£75**

STANDARD UNITS. All models are supplied as standard for mounting in 19 in. racks and are fitted with fully protective covers.

EXTRAS. To convert from rack mounting to bench use the following extras are available :—

Polished hard-wood reinforced end frames ... ... **£1 15 0** per pair

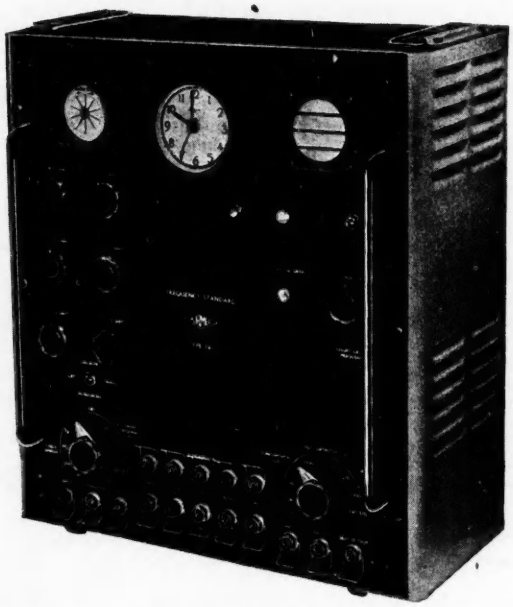
Steel instrument case of new design ... ... **£4 10 0** each

PRICES. Prices are quoted net ex works and are subject to variation without notice.

ALL-POWER TRANSFORMERS LTD. . CHERTSEY ROAD, BYFLEET, SURREY
Tel. : BYFLEET 3224/5

AIRMEC

FREQUENCY STANDARD
TYPE 761



THE AIRMEC FREQUENCY STANDARD TYPE 761 has been designed to fill the need for a self-contained frequency standard of moderate cost and high accuracy. It incorporates an oscilloscope for visual frequency comparison, and a beating circuit and loudspeaker for aural checking. A synchronous clock, driven from a voltage of standard frequency provides a time standard and enables long time stability checks to be made.

- **Master Oscillator :** **Crystal-controlled at a frequency of 100 kc/s. The crystal is maintained at a constant temperature by an oven.**
- **Outputs :** **Outputs are provided at 100 c/s, 1 kc/s, 10 kc/s, 100 kc/s and 1 Mc/s.**
- **Waveform :** **The above outputs are available, simultaneously with sinusoidal or pulse waveform from separate plugs.**
- **Stability :** **Four hours after switching on a short term stability of better than 1 part in 10^6 is obtained.**

Full details of this or any other Airmec instrument will be forwarded gladly upon request.

AIRMEC LIMITED

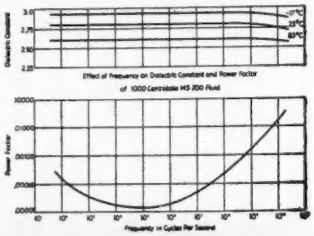
HIGH WYCOMBE · BUCKINGHAMSHIRE · ENGLAND

TEL : HIGH WYCOMBE 2060 *CABLES : AIRMEC HIGH WYCOMBE*

HEAT STABLE, WATER REPELLENT

SILICONE Dielectric materials

Now available in the following forms



LIQUID DIELECTRICS

MS 200 fluids are clear, inert liquids having almost any desired viscosity; they are notable for their heat-stability and resistance to moisture. With a permittivity about 2.75 and a power factor of less than 0.0001 from 1 kc/s to over 10 Mc/s and from —35° C. to +150° C, MS 200 fluids are unique among liquid dielectrics.

USES: Capacitors and small transformers.

DIELECTRIC COMPOUND

MS 4 compound is a non-melting, water-repellent paste which retains its grease-like consistency from —50° C to 200° C. It is highly resistant to oxidation and deterioration caused by corona discharge. Power factor is less than 0.001 up to 10 Mc/s; volume resistivity is more than 10^{12} ohm cms up to 200° C. Electric strength is more than 500 volts/mil at a 10 mil gap.

USES: Potting and sealing compound for electronic components, disconnectable plugs and sockets. Lubricant and protective agent for plastic and rubber cables, grommets and seals. Damping medium in gramophone pick-ups.

**SILASTOMER SILICONE RUBBER*

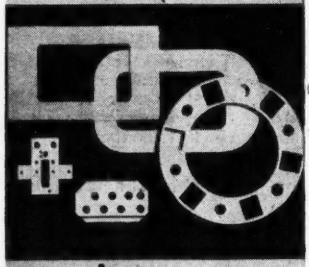
Silastomer combines the remarkable heat stability and moisture resistance of resinous silicones with the physical properties of rubber, including resilience, shock-and abrasion-resistance, and resistance to both mechanical and electrical fatigue. Its dielectric properties show little change over a wide range of frequencies, even after ageing at high temperatures. The surface resistivity of Silastomer is high, and its thermal conductivity is about twice as great as that of either organic rubber or resinous insulating materials. New Silastomer stocks and pastes with greatly improved physical properties are now available.

USES: Flexible cloth, tapes and sleeving, grommets, gaskets and terminal bushings. Flexible heater pads. Primary insulation on cables and coil end flexibles. Impregnant for coils.

SILICONE GLASS LAMINATES

Thermosetting silicone resins are used to bond inorganic fabrics and finely divided particles such as powdered metals or mica. Typical ¼" silicone-glass laminates have a tensile strength of up to 30,000 lb./sq. in. Power factor 0.002 at 1 Mc/s. Wet insulation resistance greater than 10^{10} ohms. Electric strength of 250-300 volts/mil. Effective temperature resistance of recently developed laminates, 300° C.

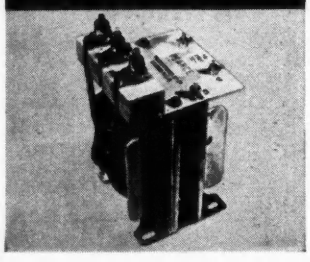
USES: These laminates can be machined and are used as panels, coil formers and structural insulation.



ELECTRICAL INSULATING VARNISHES

MS 997 is a new, low-loss impregnating varnish. It has a thermal life of more than 1,000 hours at 250° C, and shows little tendency to bubble when cured at 150° C to 200° C.

USES: Impregnating coils, resistors and components subjected to high temperature and humidity.



**SILASTOMER is a registered trademark of Midland Silicones Ltd.*

Write for full information to:

MIDLAND SILICONES LTD

An Associate Company of Albright & Wilson Ltd.

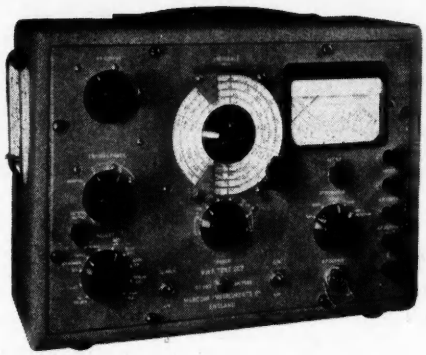
FOR BRITISH MADE SILICONES 19 Upper Brook Street, London, W.1. Tel: Grosvenor 4551 TBW/MS98

Marconi V.H.F. Test Set Type TF 982

For Mobile Transceivers

For the overall checking of a.m. transmitters and receivers, particularly of the mobile type, the Test Set is primarily a v.h.f./i.f. signal generator with 1,000 c/s modulation facilities; it may also be used as an a.f. and r.f. power meter, a variable-level a.f. source, an r.f. local field detector and a five-range a.c./d.c. test meter.

The signal generator section provides four v.h.f. ranges covering from 60 to 200 Mc/s and four i.f. ranges, each having a bandwidth of 250 kc/s, centred at 1.6, 2.1, 4.86 and 5.0 Mc/s respectively. Facilities are provided for crystal standardisation at the centre frequency of each i.f. range. The v.h.f./i.f. output is derived via a step attenuator and terminating unit giving calibrated outputs from 2μV to 2 mV at 52 and 75 ohms; uncalibrated outputs up to a maximum of 400 mV are also available.



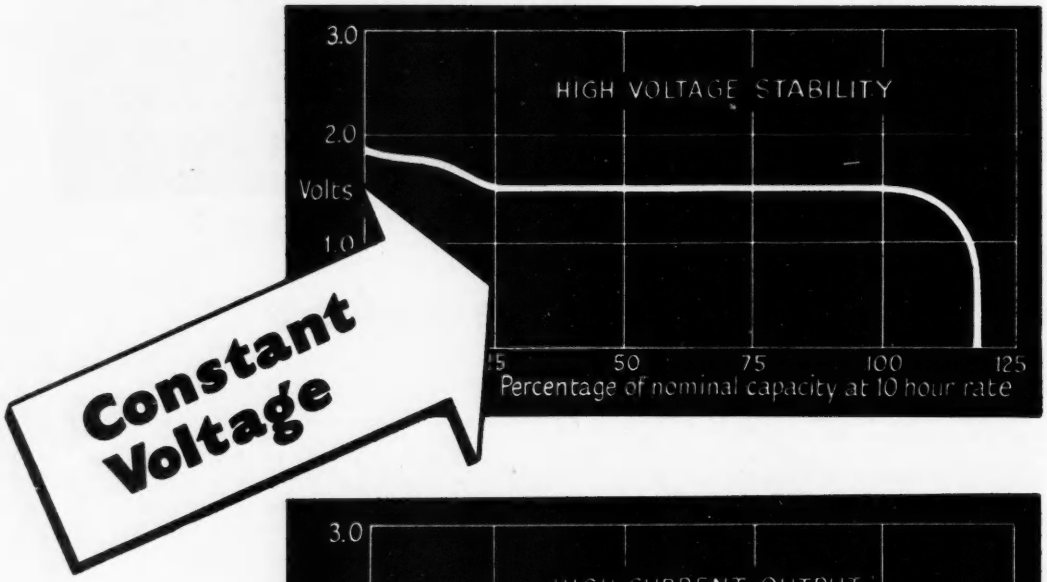
MARCONI INSTRUMENTS

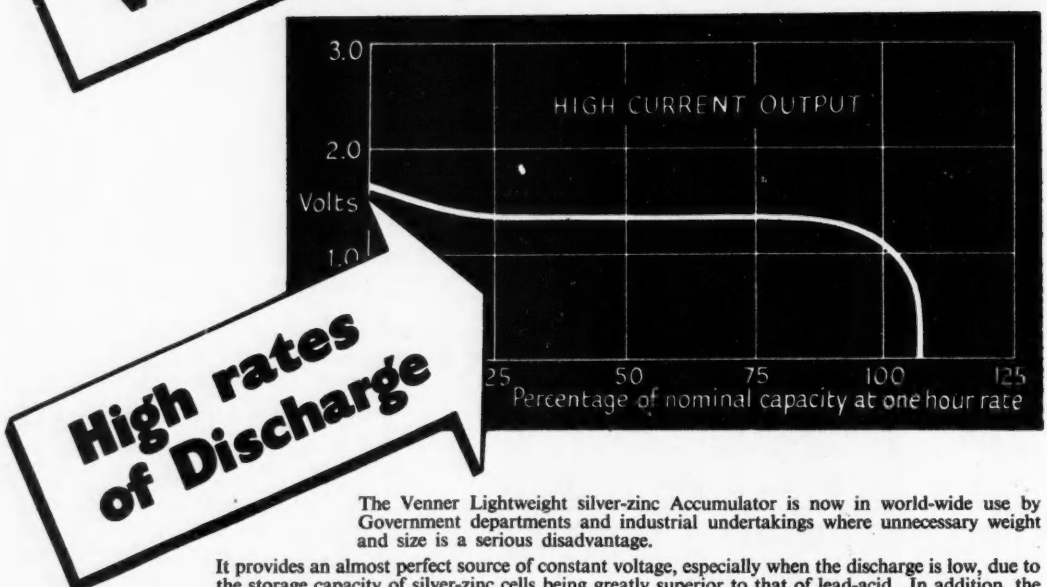
Signal Generators · Bridges · Valve Voltmeters · Q. Meters · Wavemeters
Frequency Standards · Wave Analysers · Beat Frequency Oscillators

MARCONI INSTRUMENTS LTD · ST. ALBANS · HERTS · TELEPHONE: ST. ALBANS 6161/7

Midland Office: 19 The Parade, Leamington Spa **Northern Office:** 30 Albion Street, Kingston-upon-Hull
Export Office: Marconi House, Strand, London, W.C 2

Outstanding Characteristics

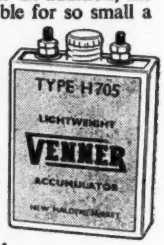




The Venner Lightweight silver-zinc Accumulator is now in world-wide use by Government departments and industrial undertakings where unnecessary weight and size is a serious disadvantage.

It provides an almost perfect source of constant voltage, especially when the discharge is low, due to the storage capacity of silver-zinc cells being greatly superior to that of lead-acid. In addition, the extreme high rates of discharge with little drop in effective capacity is remarkable for so small a rechargeable battery and is equivalent to, and exceeds in many cases, the ordinary cumbersome and heavyweight types.

The Venner Lightweight Accumulator is exceptionally valuable for aircraft and marine applications, miners' lamps, photographic flash outfits and all battery operated electronic devices.



Write for illustrated technical literature

VENNER ***Lightweight*** **SILVER-ZINC ACCUMULATOR**

The smallest and lightest accumulator in the world.

VENNER ACCUMULATORS LTD · KINGSTON BY-PASS · NEW MALDEN · SURREY. **Tel : MALden 2442 (7 lines).**

Associated Companies : VENNER LIMITED VENNER ELECTRONICS LIMITED.

The *NEW* Muirhead-Wigan decade oscillator

TYPE D-650-A

THIS precision laboratory oscillator, which covers a range of 1 to 111,100c/s with an overall frequency accuracy of ±0.2% or ±0.5c/s, employs the decade tuning system, by means of which the frequency can be set quickly and accurately on four decade dials and a range switch. This system of tuning ensures the highest possible frequency accuracy and stability. It also enables a given frequency setting to be repeated exactly, and permits the addition or subtraction of a fixed number of cycles per second, thus giving an incremental accuracy of an extremely high order. No other type of oscillator possesses all these advantages.

FEATURES

Frequency range: 1-11,110c/s and 10-111,100c/s.

Frequency accuracy: ±0.2% or ±0.5c/s.

Hourly frequency stability: ±0.02% over most of range.

Maximum output:
2W into 8000 ohms above 20c/s.
50mW into 8000 ohms below 20c/s.

Harmonic content: 1% at 1W output.

Hum level: —80db relative to maximum output at 1000c/s.

Power supply: 200-250V, 50c/s; 90W. or 95-125V, 60c/s; 90W.

Dimensions: 17¼ in. wide x 10½ in. high x 13 in. deep. (43·8 cm x 26·7 cm x 33 cm).

Weight: 83 lb. (38 kg).

MAIL THIS COUPON FOR DESCRIPTIVE BROCHURE

NAME_____

POSITION_____

COMPANY_____

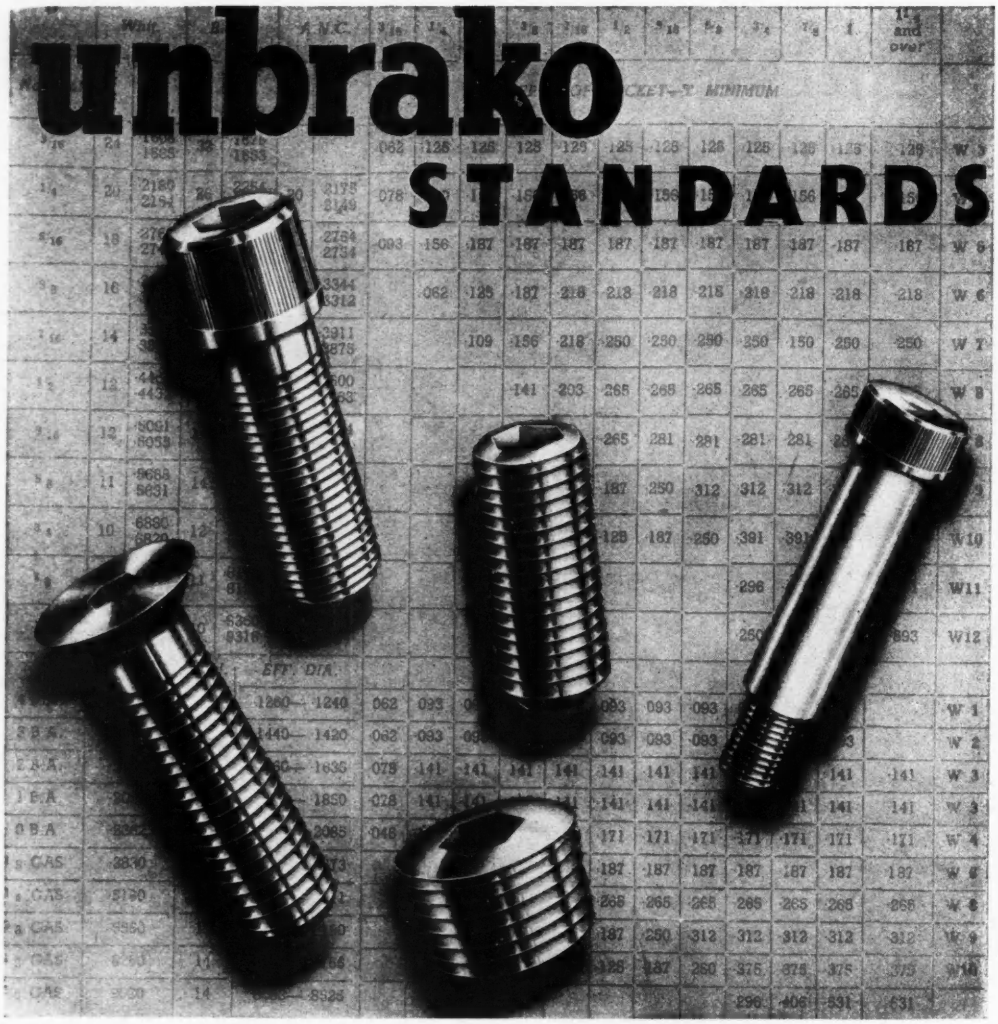
ADDRESS to which BROCHURE should be sent

_____

_____

114

MUIRHEAD & CO. LIMITED · BECKENHAM · KENT · ENGLAND



What are Unbrako standards?

Didn't you know? Well, they're the five types of socket head screws which you see illustrated. Precision formed, close tolerance screws which meet the everyday needs of engineering.

Available in B.S.F., Whitworth, B.A., Metric, A.N.C., A.N.F., and Unified threads in all sizes.

UNBRAKO

Made to the exacting quality specification
of the world's largest specialist screw manufacturers,
they are always obtainable from Unbrako Distributors throughout the world.

UNBRAKO SOCKET SCREW CO. LTD.
COVENTRY ENGLAND

GLASS FABRIC LAMINATES

We are the leading manufacturers of glass fabric laminates in this country and specialize in the manufacture of components both as standard lines and to customers' specifications. We will be pleased to advise you on a suitable laminate for any application where lightness in weight, strength and electrical or chemical resistance, combined with non-corrosive and anti-magnetic properties are of paramount importance.

Please write for details of our large range of standard size tubes and sheeting.

THERMO-PLASTICS LTD

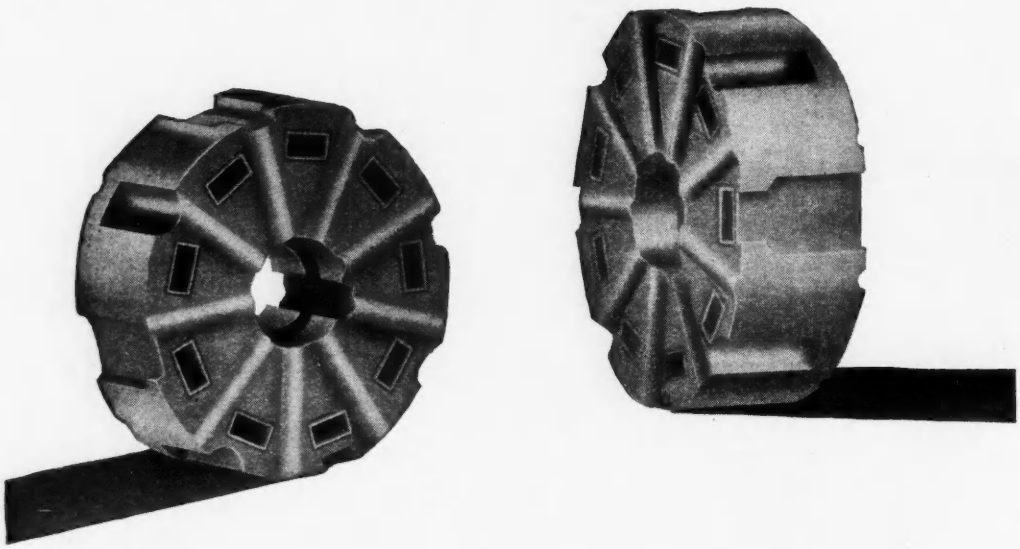
Moulders & Fabricators of ALL Plastic Materials

Specialists in Perspex, Cellulose-Acetate, Rigid P.V.C. Polyethylene fabrications; glass laminates and bonding of rubber to Perspex and metal; compression and injection mouldings in Phenolic, Urea, Formaldehyde, Polyethylene, Polystyrene, Cellulose-Acetate, etc.

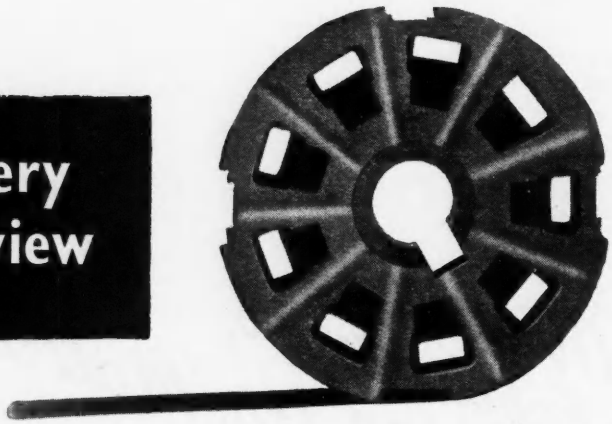
TP DUNSTABLE

THERMO-PLASTICS LTD. • DUNSTABLE • BEDS

Telephone: DUNSTABLE 686/7/8 and 777 *Telegrams:* THERMOPLASTICS, DUNSTABLE



from every point of view



Frequentite is the most suitable insulating material for all high frequency applications. Seventeen years ago we introduced the first British-made low-loss ceramic, and consultation with us before finalising the design of new components is a wise precaution.

STEATITE & PORCELAIN PRODUCTS LTD.

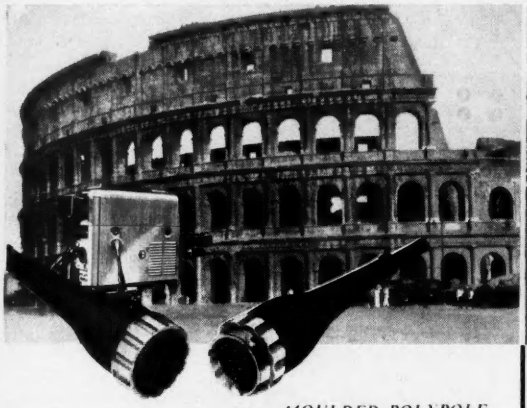
Head Office: Stourport-on-Severn, Worcestershire. Telephone: Stourport 111. Telegrams: Steatain, Stourport

S.P.67

BICC

PRODUCTS FOR TELECOMMUNICATIONS

BICC are constantly developing new products and improving existing ones to help solve the problems of the telecommunications engineer. The examples illustrated indicate the extent of their research and development work in this field. Like all BICC products, they are made to realistic specifications from the highest quality materials. They will give long, reliable service in any climate.



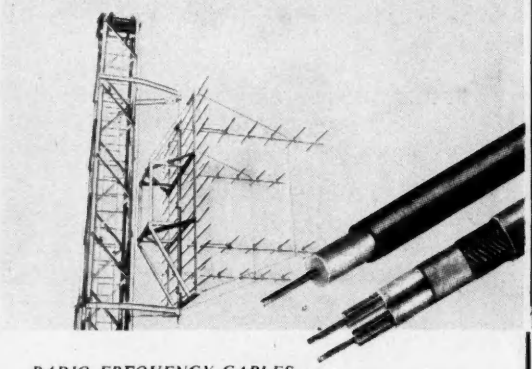
MOULDED POLYPOLE CABLE COUPLERS

These are moulded to the ends of television camera cables in the factory, providing a robust trailing cable system. The cameras supplied by Marconi's Wireless Telegraph Co. Ltd., to the Italian State Broadcasting Corporation—part of the biggest order for television equipment ever placed in Britain—are equipped with BICC cables and couplers.

TELEPHONE CABLES

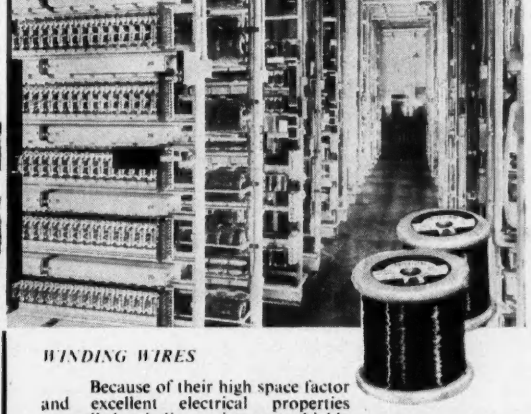
Nearly every type of cable and wire for use in telephone systems is manufactured by BICC. Of particular interest are the spaced polythene disc type co-axial cables for multi-channel operation. Also available are standard dry-core cables for trunk and distribution use, and plastic cables to meet a variety of operating conditions.

Photo by courtesy of H.M. Postmaster-General.



RADIO FREQUENCY CABLES

BICC make a comprehensive range of radio frequency cables. A medium power aluminium-sheathed co-axial cable will provide the main feeder to the V.H.F. aerial installation shown above. The aerial is to be used with equipment designed by the Automatic Telephone and Electric Co. Ltd.



WINDING WIRES

Because of their high space factor and excellent electrical properties enamelled winding wires are highly suitable for small coils and windings. They are widely used in telephone relay coils. BICC manufacture winding wires for all purposes, insulated with oil-base or synthetic enamels, textiles, paper, glass and asbestos.

Photo by courtesy of H.M. Postmaster-General.

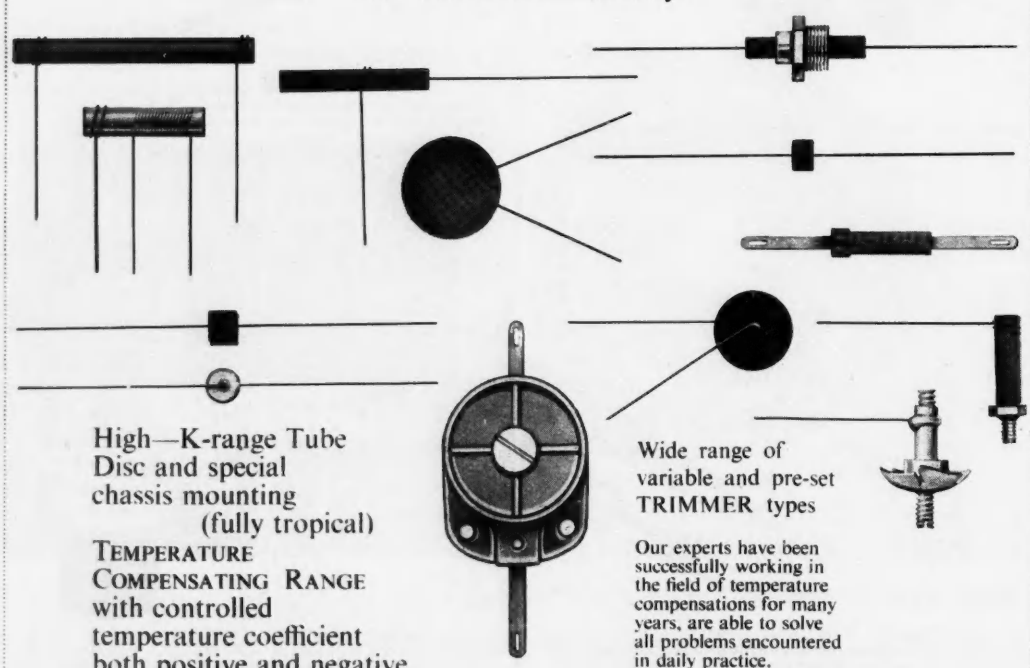
Branches and Agents throughout the World

BRITISH INSULATED CALLENDER'S CABLES LIMITED
21 BLOOMSBURY STREET, LONDON, W.C.1. Museum 1600

ST
CON

The Sign of Quality and Reliability

By the application of new DIELECTRIC ceramics and production technique our CERAMIC CAPACITORS have set a new standard of excellence. Built to meet the most exacting requirements of today's Radio-Television and Electronic Industry.



High—K-range Tube Disc and special chassis mounting (fully tropical)

TEMPERATURE COMPENSATING RANGE with controlled temperature coefficient both positive and negative (fully tropical)

Wide range of variable and pre-set TRIMMER types

Our experts have been successfully working in the field of temperature compensations for many years, are able to solve all problems encountered in daily practice. Full details of capacitors available on application.

STEATITE INSULATIONS LTD.

25 SOMERSET ROAD, EDGBASTON, BIRMINGHAM, 15.

Tel. EDGbaston 3990

Tel. Add. " STEATITE - BIRMINGHAM, 15 "

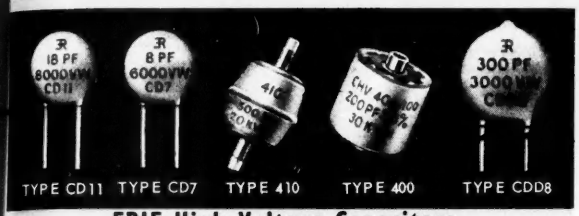
There is a v
various app
30 kV.

Available i
voltages fr
Capacity va
tionally sm

The larges
temperature
ues ranging

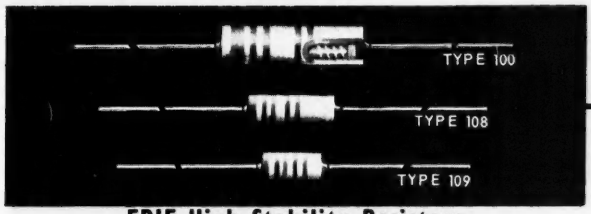
demand

. . . exacting quality in capacitors and resistors



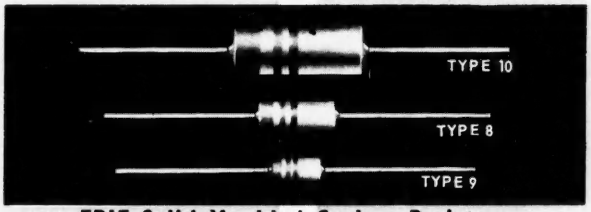
ERIE High Voltage Capacitors

There is a wide selection of disc and moulded Ceramicons* for various applications, covering voltages up to a maximum of 30 kV.



ERIE High Stability Resistors

The only resistor of this class in which the supersensitive carbon film is ceramic encased. Available in ratings of ¼ watt, ½ watt and 1 watt, in values ranging from 10 ohms to 3 megohms, and in tolerances down to ±1%.

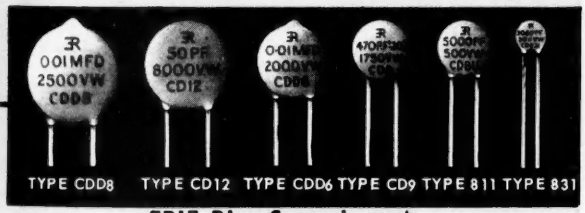


ERIE Solid Moulded Carbon Resistors

Available in ratings of ¼ watt, ½ watt and 1 watt, either phenolic or ceramic insulated, in values ranging from 10 ohms to 10 megohms, and in tolerances down to ±5%.

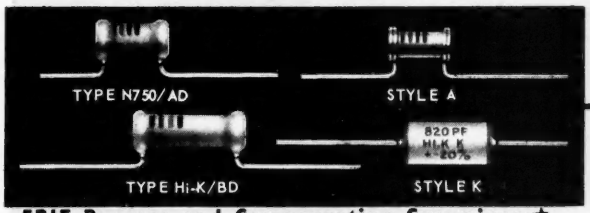
ERIE*

dependable electronic components



ERIE Disc Ceramicons*

Available in values ranging from 2.5 PF to 30,000 PF in working voltages from 500 to 8 kV, and in tolerances down to ±10%. Capacity variations with temperature, age, and voltage are exceptionally small. A truly outstanding range.



ERIE By-pass and Compensating Ceramicons*

For by-pass requirements, there are three types available in values ranging from 220 to 18,500 PF. For compensating, there are nine types in temperature coefficients ranging from P100 to N750, available in values up to 1480 PF.

ERIE Trimmer Capacitors

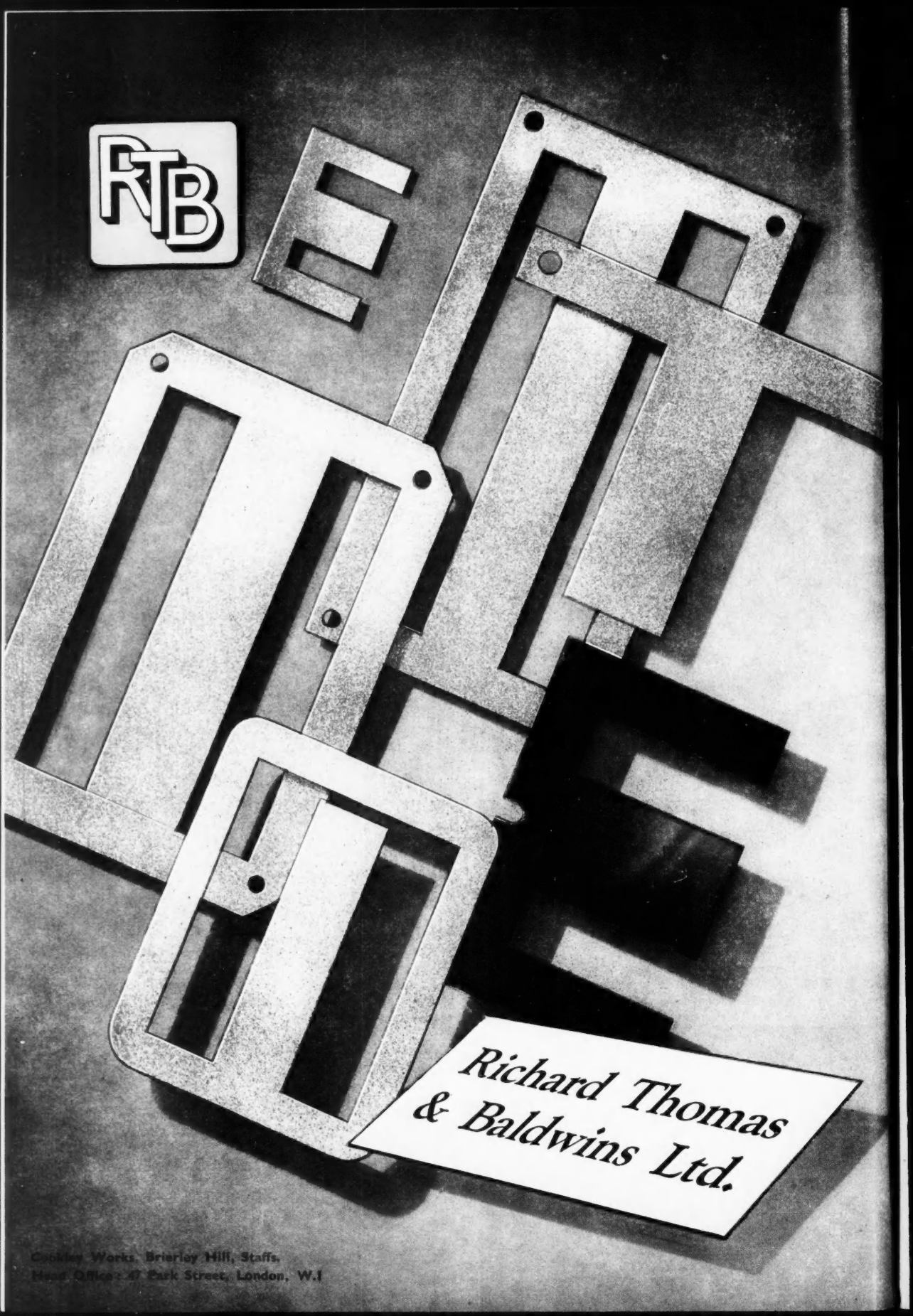
The largest and most versatile range of plastic and ceramic temperature compensating trimmer capacitors. Available in values ranging from 0.5 PF minimum to 30 PF maximum.

ERIE Stand-off and Feed-thru Ceramicons*

Specially designed to overcome radiation and critical by-passing problems. Available in values up to 1500 PF.

*Registered Trade Marks

ERIE RESISTOR LIMITED, Carlisle Road, The Hyde London, N.W. 9., England. *Factories: London and Great Yarmouth, England; Toronto, Canada; Erie, Pa., U.S.A.*


RTB
Richard Thomas
& Baldwins Ltd.
Cookley Works, Brierley Hill, Staffs.
Head Office: 47 Park Street, London, W.1

It is
that
inside
than

We

THE

Phone

CRAV

MAR
E

Spring Quiz
No. 4

what is
the wahl factor?

It is merely a correction of the fact that a higher fibre stress exists on the inside coil surface of a loaded spring than on the outer surface.

We make good-tempered springs !

F.S. Ratcliffe
(ROCHDALE) LIMITED
THE SPRING SPECIALIST

REGISTERED RECOIL TRADE MARK

Phone: Rochdale 4692/3 Grams: Recoil, Rochdale

CRAWFORD SPRING WORKS, ROCHDALE, LANCS

Electronic Engineering

Incorporating 'ELECTRONICS, TELEVISION and SHORT WAVE WORLD.
Managing Editor H. G. Foster M.Sc. M.I.E.E.

Vol. XXVI **MARCH 1954** No. 313

Contents

Commentary	89
Some Steady-State Characteristics of Short Irregular Lines — By A. Rosen	90
Underwater Television	96
A Square Root-Law Circuit — By I. G. Baxter	97
Maintaining Optimum Cycling Intervals in a Two-Step Controller — By W. R. Beakley	99
The Measurement of Very Small Direct Currents — By M. W. Jervis	100
Flight Simulators for Canada	105
Voltage Stabilizers for Microwave Oscillators — By F. A. Benson and G. V. G. Lusher	106
An Electrical Backlash Circuit — By C. H. Banthorpe	110
A Relay Operated Unit for the Measurement of the Relative Slip Between Two Rollers — By G. J. Parish	112
D.C. Amplifiers (Part 3) — By J. Yarwood and D. H. Le Croissette	114
The Use of Cold Cathode Counting Tubes in Cascade — By D. T. Whelan	118
A Low-Pass Filter with a Continuously Variable Cut-off Frequency — By J. W. Thompson	120
Step to Frequency Response Transforms for Linear Servo Systems (Part 3) — By L. C. Ludbrook	122
Short News Items	127
Book Reviews	128
Electronic Equipment	130
Letters to the Editor	132
Meetings this Month	134

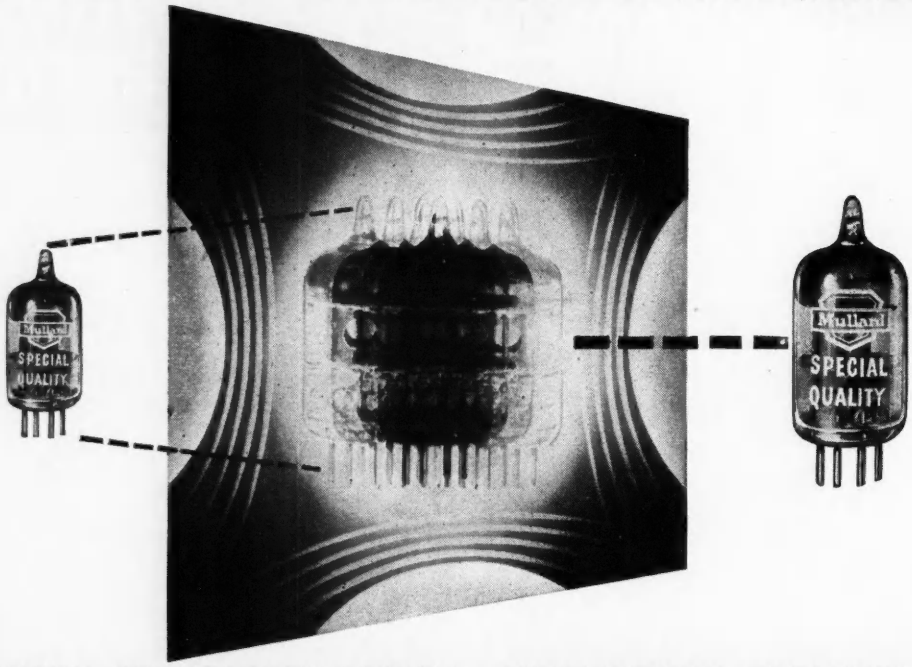
Published Monthly on the last Friday of the preceding month at 28 Essex Street, Strand, London, W.C.2.

Telephone: CENTRAL 6565
Telegrams: 'LECTRONING, ESTRAND, LONDON'

Subscription Rate:
(Home or Abroad) Post Paid 12 months 26s. or $3.75 (U.S.)

Classified Advertisements, Page 1
Index to ADVERTISERS, 102

TESTED TO SPECIFIED EXTREMES



SHOCK • VIBRATION FATIGUE • MECHANICAL RESONANCE GLASS STRAIN • RELIABLE LIFE

New production methods and exhaustive tests assure users of Mullard *Special Quality* Valves of the definite standard of reliability laid down in Ministry of Supply (Air) Specifications.
Large-scale production of valves which are capable of withstanding such arduous conditions of shock and vibration presents obvious difficulties. These problems have been vigorously investigated over the past five years by Mullard who have now evolved techniques which make *Special Quality* Valves an economic reality for a wide variety of electronic equipment.
The first types in a comprehensive Mullard range are now generally available and are listed below. Details of the availability of types at present under advanced development will be announced soon.

Mullard Special Quality Type No.	Description	Electrical Equivalent		
		Mullard	American	British Services
M8079	Double Diode with separate cathodes	EB91	6AL5	CV140
M8081	Double Triode for use as R.F. amplifier or oscillator	ECC91	6J6	CV858
M8082	Output Pentode	EL91	—	CV136
M8083	High-slope R.F. Pentode	EF91	—	CV138
M8100	Low-noise high-slope R.F. Pentode	EF95	6AK5	CV850

Mullard
SPECIAL QUALITY VALVES
TESTED TO SPECIFIED EXTREMES

MULLARD LTD., COMMUNICATIONS & INDUSTRIAL VALVE DEPT., CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2
MVT 153

ELECTRONIC ENGINEERING

VOL. XXVI No. 313

MARCH 1954

Commentary

THE story of the wartime collaboration between American and British scientists in the successful development of the atomic bomb is well known.

It is now a matter of history that at the beginning of the war the possibility of an atomic weapon loomed very prominently in the strategy of the day and after some preliminary studies a committee, disguised under the name of Directorate of Tube Alloys, was set up to further this project.

Parallel work had been going on in America and after a visit of American scientists to this country in 1941 it was later decided that the whole of this work on the development of the atomic bomb should be concentrated in America. The entire British team was sent over, and no further development work was done in this country. So began the joint British, Canadian and American collaboration which continued until the end of the war.

With the cessation of hostilities and the uneasy years which followed America deemed it unwise for her to continue this wartime collaboration, and in 1946 she passed the McMahon Act which virtually brought matters to an end.

While the fundamental principles on which the atomic bombs were based are well known, the actual methods by which the bombs had been produced—the "know how"—continued to remain the secret of the United States. British scientists had, however, contributed much to the original wartime research and working on their own since 1946 have developed atomic weapons of advanced types which are now in production.

All this, too, is well known and the layman can be forgiven if he associates the production of atomic energy only with weapons of mass destruction. The very complexities of this new science make it difficult to appreciate that the enormous energy which can now be released from the nucleus of the atom, far from wiping out civilization can, in a saner world, bring untold comfort and well being to the human race.

It was obvious that a highly industrialized country like Great Britain could not afford to ignore the promising industrial applications of this new form of energy for apart from other considerations, the industrial prosperity of this country is based on coal, adequate supplies of which have already become increasingly difficult and costly to obtain.

Accordingly, towards the end of 1945 the Government decided to set up a research and development establishment at Harwell covering all aspects of atomic energy and this was shortly followed by a Division of Atomic Energy Production "to make available as rapidly as possible material in sufficient quantity to enable us to take advantage rapidly of technical developments as they occur."

Thus was born a vast new industry involving the expenditure of hundreds of millions of pounds and employing thousands of workers in it. It is the industry engaged in the production of fissile material and the story of its birth and early struggles is told for the first time in a fascinating booklet entitled "Britain's Atomic Factories", which has just been published by the Stationery Office.

Much of the work of the Division of Atomic Energy Production still remains secret but "now that we have moved on from the purely research stage into that of regular manufacture", writes Mr. Duncan Sandys, the Minister of Supply, in a foreword to this book, "it is right that the world should be told how fissile material is today being produced in Britain and of the remarkable factories and plant which have been designed and erected to carry out these strange processes."

Strange processes and remarkable factories they are without question, for few of us have the intimate knowledge fully to understand the exact methods by which the fissile materials are produced and "Britain's Atomic Factories" does not set out to enlighten us, but the reader cannot fail to be thrilled as the story of the growth of these enormous laboratories—factories seems an inappropriate word—is told.

It is the story of the task presented to Sir Christopher Hinton—merely a brief instruction to produce annually a certain quantity of plutonium to a given specification in water-cooled piles—and how this task has been successfully accomplished with the bringing into being of the Production Division at Risley and the factories at Springfield, Windscale and Capenhurst.

The production of fissile material may be said to have begun on 4th February, 1946, when the nucleus of the Production Division was formed at Risley and a total staff of twelve moved into their new headquarters. How modest was this beginning may be judged from the fact that of this staff only one member had had previous experience in the development of atomic energy and almost one of the first tasks was to instruct him to explain to the remaining members in the simplest of terms what atomic energy was. Yet from these humble beginnings the development of atomic energy has grown apace—not, of course, without many setbacks which are frankly discussed in the book—but today it is fair to claim that this country is again in the forefront.

Some Steady-State Characteristics of Short Irregular Lines

By A. Rosen*, A.C.G.I., Ph.D., M.I.E.E.,

The distribution of irregularities of impedance along a line is represented by a Fourier series, and relations are obtained between the input-impedance deviations and the Fourier coefficients. These are considered in detail at the resonant frequencies, with particular application to the short line; when the input-deviations measured at the two ends are available, their relations to the Fourier coefficients are specially simple, and permit the distribution of impedance irregularities along the line to be synthesized. The measurement of the complex deviations, and the effects of the line irregularities on the open- and short-circuit impedances are considered. Finally the measurement of mean impedance and attenuation coefficient is dealt with, and a brief description is given of a bridge having variable capacitance ratio arms, which is used for testing factory lengths of coaxial cable.

THE theory of the nominally homogeneous line having small impedance irregularities distributed along its length has been studied extensively[1-6], because of its importance in the transmission of wideband telephony and television through coaxial cables. These cables are usually manufactured in lengths of the order of 0·1 mile, and in this article some of the more important electrical characteristics of such factory lengths are considered, the treatment being confined to the steady-state properties.

So far, one type of coaxial pair has been standardized in this country and abroad for long-distance transmission, and pulse-echo measurements[7,12] have largely superseded the older steady-state tests for the routine measurements of irregularities on such cables. The pulse tests, however, are not yet standardized, and, moreover, they require expensive simulating networks particular to each type of cable. Thus there is still an important field for steady-state irregularity measurements, e.g. in checking and correlating pulse-echo tests on standardized cables and for measuring experimental lengths of a type for which simulating networks are not available.

List of Symbols

(*The* M.K.S. *System of Units is Employed*)

$j = \sqrt{-1}$
f = frequency
f_M = frequency in megacycles per second
$\omega = 2\pi f$
C_u = capacitance per unit length of uniform line
L_u = inductance per unit length of uniform line
l = length of line
x = distance of point X from sending end
Z = impedance
R = resistive component of Z
X = reactive component of Z
Z_m = mean characteristic impedance
ϕ_m = angle of Z_m
Z_r = reference impedance
γ = mean propagation coefficient per metre
α = mean attenuation coefficient per metre
β = mean phase-change coefficient per metre
p = reflexion coefficient
δZ = input-impedance deviation relative to Z_r
δr = resistive component of δZ
δx = reactive component of δZ
ΔZ = input-impedance deviation relative to Z_m
Δr = resistive component of ΔZ
Δx = reactive component of ΔZ
σ = deviation of local characteristic impedance from Z_r
S = deviation of local characteristic impedance from Z_m
s = order of term in Fourier series
H_s = coefficient of sine term in Fourier series
J_s = coefficient of cosine term in Fourier series
n = order of resonant frequency
k_1, k_2 = correction terms given by equations (21) and (22)
M, N = factors given by equations (37) and (38)
δf = small change of frequency
θ = small change of phase-change coefficient
K = factor modifying open- and short-circuit impedances
r = difference of "resistance" readings on impedance bridge

SUBSCRIPTS

AB pertaining to line AB
A or B pertaining to end A or B of line AB
X pertaining to point X
r pertaining to reference impedance
m pertaining to mean impedance
op pertaining to line with far end open-circuited
sh pertaining to line with far end short-circuited
n pertaining to order of resonance
u pertaining to unit length of uniform line

ACCENTS

′ pertaining to odd resonant frequency
″ pertaining to even resonant frequency

The disturbing effect of impedance irregularities is due to echoes, produced by double reflexions, which accompany the main signal. A pulse method is available for assessing the doubly-reflected echoes in a short line[10], but no method has so far been devised for measuring these effects in the steady state. However, the irregularities in short lengths are adequately characterized by their single-reflexion effects, and very nearly all factory lengths of coaxial cable are assessed on this basis.

* *Formerly Siemens Brothers and Company Limited, now with British Insulated Callender's Cables Ltd.*

Definitions

The short line with which we are concerned in this article is defined as one for which the overall attenuation coefficient is small, say not greater than 0·2 neper, although the line may be several wavelengths long. Consider such a short line AB, of length l, having small impedance irregularities distributed along it. If Z_x, γ_x are the respective values of the local characteristic impedance and the propagation coefficient per unit length at a point distant x from the sending end, then the mean characteristic impedance Z_m is defined as

$$Z_m = \frac{1}{l}\int_0^l Z_x dx \quad \ldots\ldots\ldots\ldots (1)$$

and the mean propagation coefficient γ per unit length is

$$\gamma = \frac{1}{l}\int_0^l \gamma_x dx \quad \ldots\ldots\ldots\ldots (2)$$

The "reference impedance" is an arbitrary impedance close to Z_m, and is defined precisely in another paper[13]; here it is the value of the impedance used for terminating the short line. The input-impedance, Z_{AB}, is defined as the impedance measured at A when the line is terminated at B by the reference impedance.

The reflexion coefficient, which expresses the relation between the emitted wave and the reflected voltage at the sending end, is also defined precisely elsewhere[13]; for the present purpose, it is sufficient to define the reflexion coefficient p_{AB} by the relation

$$p_{AB} = (Z_{AB} - Z_r)/(Z_{AB} + Z_r) \quad \ldots\ldots\ldots (3)$$

The input-impedance deviation of AB with respect to Z_r, $\delta Z_{AB} \equiv \delta r_{AB} + j\delta x_{AB}$, is defined as the difference between Z_{AB} and Z_r. Thus

$$p_{AB} = \delta Z_{AB}/(Z_{AB} + Z_r) \quad \ldots\ldots\ldots\ldots (4)$$

and since we are concerned only with small irregularities:

$$p_{AB} = \delta Z_{AB}/2Z_r \quad \ldots\ldots\ldots\ldots (5)$$

The basic equation in the theory of irregular lines was first given by Didlaukis and Kaden[1]. It may be stated as[13]

$$p_{AB} = \frac{\gamma}{Z_r}\int_0^l \sigma_x \exp(-2\gamma x)dx \quad \ldots\ldots\ldots (6)$$

where

$$\sigma_x = Z_x - Z_r \quad \ldots\ldots\ldots\ldots (7)$$

Thus

$$\delta Z_{AB} = 2\gamma\int_0^l \sigma_x \exp(-2\gamma x)dx \quad \ldots\ldots\ldots (8)$$

When the mean impedance is selected as reference impedance, we denote the impedance deviation by $\Delta Z_{AB} \equiv \Delta r_{AB} + j\Delta x_{AB}$, and we have

$$\Delta Z_{AB} = Z_{AB} - Z_m = 2\gamma\int_0^l S_x \exp(-2\gamma x)dx \quad \ldots\ldots\ldots\ldots (9)$$

where

$$S_x = Z_x - Z_m \quad \ldots\ldots\ldots\ldots (10)$$

Whence

$$\Delta Z_{AB} = \delta Z_{AB} + (Z_r - Z_m)\{1 - \exp(-2\gamma l)\}. \quad (11)$$

[It should be noted that Didlaukis and Kaden[1] and some other writers have used ΔZ for the *real* part of the input-impedance deviation; in this article, ΔZ, δZ, are *complex* quantities, as defined above.]

Particular reference is made below to the "104/375" type of coaxial pair, which has been standardized by the British Post Office[11]. This consists of an inner solid copper conductor 0·104in in diameter, insulated with polythene disks at intervals of about 1·3in, with an outer tubular copper conductor having an internal diameter of 0·375in and a thickness of 0·010in. This type of coaxial pair is at present operated within the frequency range 0·06 to 4·5Mc/s, and in this band of frequencies, its attenuation and phase-change per mile are given by the following:

$$\alpha = 0{\cdot}432\, f_M^{\frac{1}{2}} \text{ neper/mile}$$

$$\beta = 34{\cdot}8\, f_M + 0{\cdot}4\, f_M^{\frac{1}{2}} \text{ radian/mile}$$

where f_M is the frequency in Mc/s. The characteristic impedance is given very closely by the expression:

$$Z_m = 74{\cdot}4 + 0{\cdot}9(1 - j)f_M^{-\frac{1}{2}} \text{ ohms.}$$

Length Distribution of Impedance as a Fourier Series

The single reflexions from any line can be predetermined over a range of frequencies by means of equations such as (6) providing the length-distribution of impedance is known in detail along the whole line, but such computations are extremely laborious. Cotte[6] has suggested that the impedance-distribution may be represented by a Fourier series, and this generalization enables us to make some useful deductions regarding the properties of lines, particularly when they are short, without imposing any restriction on the distribution of the irregularities; moreover, as shown below we can readily measure the coefficients of the Fourier series for a particular short line and thereby synthesize its impedance-distribution curve.

For any line of length l we may write for $0 < x < l$

$$Z_x = Z_m + \sum_{s=1}^{\infty}\left(H_s \sin\frac{2s\pi x}{l} + J_s \cos\frac{2s\pi x}{l}\right) \ldots\ldots (12)$$

In general the coefficients H_s, J_s, are complex quantities which vary with frequency. If, however, the line considered is a coaxial pair with small irregularities such as occur in practice, the chief factors causing impedance deviations are local variations of conductor dimensions and of effective permittivity; these produce first order changes in the resistive component of the impedance and only second order changes in the reactive component, which can be neglected. In these circumstances the Fourier coefficients H_s, J_s, may be regarded as being wholly real quantities; furthermore, provided the frequency is not too low, the coefficients are sufficiently independent of frequency for practical purposes. By combining equations (12) and (8) we obtain

$$\delta Z_{AB} = (Z_m - Z_r)\{1 - \exp(-2\gamma l)\} + 2\int_0^l \exp(-2\gamma x)\sum_{s=1}^{\infty}\left(H_s \sin\frac{2s\pi x}{l} + J_s \cos\frac{2s\pi x}{l}\right)dx \ldots (13)$$

Since $\int \exp(ax)\sin bx\, dx = \dfrac{\exp(ax)(a\sin bx - b\cos bx)}{a^2 + b^2}$

$$\int \exp(ax)\cos bx\, dx = \frac{\exp(ax)(a\cos bx + b\sin bx)}{a^2 + b^2}$$

we have

$$\delta Z_{AB} = \{1 - \exp(-2\gamma l)\}\left[Z_m - Z_r + \gamma l\sum_{s=1}^{\infty}\frac{s\pi H_s + \gamma l J_s}{\gamma^2 l^2 + s^2\pi^2}\right] \ldots\ldots (14)$$

The input-impedance deviation is thus composed of two parts: an external component which depends on $Z_m - Z_r$, i.e. on the difference in level between the mean impedance and the reference impedance, and an internal component which depends only on the internal irregularities of the line. When the reference impedance is equal to the mean impedance we have

$$\Delta Z_{AB} = \{1 - \exp(-2\gamma l)\}\,\gamma l\sum_{s=1}^{\infty}\frac{s\pi H_s + \gamma l J_s}{\gamma^2 l^2 + s^2\pi^2} \ldots\ldots (15)$$

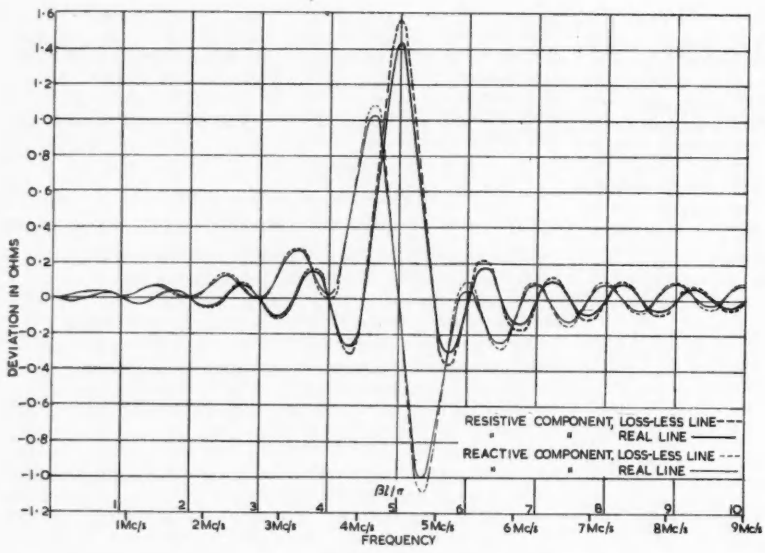


Fig. 1 (a). 0·1 mile, 104/375 coaxial pair

$$S_x = 0{\cdot}1 \sin \frac{10\pi x}{l}$$

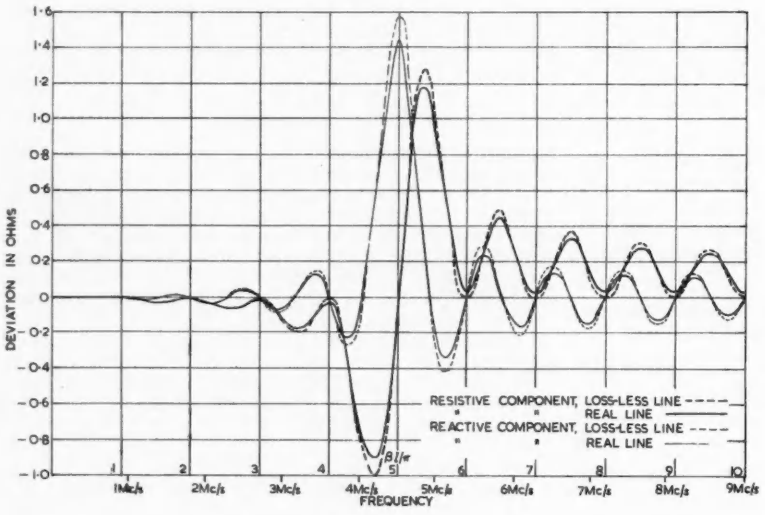


Fig. 1 (b). 0·1 mile, 104/375 coaxial pair

$$S_x = 0{\cdot}1 \cos \frac{10\pi x}{l}$$

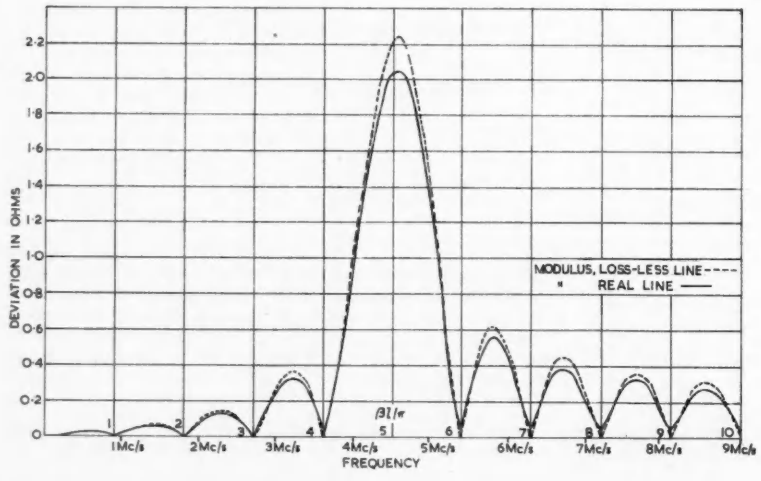


Fig. 1 (c). 0·1 mile, 104/375 coaxial pair

$$S_x = 0{\cdot}1 \sin \frac{10\pi x}{l} + 0{\cdot}1 \cos \frac{10\pi x}{l}$$

To obtain an idea of the contributions of the various terms we may consider a line in which the irregularities consist of pure sine and cosine waves of a single periodicity; thus in Fig. 1, ΔZ is shown for the case for which $S_x = H_s \sin 10\pi x/l + J_s \cos 10\pi x/l$, the contributions of the sine and cosine terms being drawn separately. The line is 1/10 mile of 104/375 coaxial cable, and ΔZ is shown for the cases where attenuation is neglected and where it is taken into account. It will be seen that ΔZ reaches a maximum at the even resonant frequency corresponding to $2\beta l = 10\pi$, and is very small at all the other even resonant frequencies. The resonant frequencies display features of special interest and are considered below; for convenience, quantities related to the odd and even resonant frequencies are distinguished by single and double primes respectively.

Input-impedance Deviations at Even Resonant Frequencies

At even resonance when $2\beta l = n''\pi$, the term in equation (15) for which $s = \frac{1}{2}n''$ predominates over all the others. Thus since since $\alpha \ll \beta$, we have

$$\Delta Z''_{AB} = \left\{1 - \exp(-2\alpha l)\right\}\left[\frac{n''\pi}{4\alpha l}\left((H''_{\frac{1}{2}n} + jJ''_{\frac{1}{2}n}) + \right.\right.$$
$$\left.\left. + \tfrac{3}{4}J''_{\frac{1}{2}n} - \tfrac{1}{4}jH''_{\frac{1}{2}n} + \right.\right.$$
$$\left.\left. + \sum_{\substack{s=1 \\ (\neq \frac{1}{2}n'')}}^{\infty} \frac{J_s - 2jH_s s/n''}{1-(2s/n'')^2 - 4j\alpha l/n''\pi}\right] \quad \ldots\ldots\ldots\ldots (16)$$

When the line is short, i.e., αl is small,

$$\Delta Z''_{AB} = \tfrac{1}{2}n''\pi(1 - \alpha l)(H''_{\frac{1}{2}n} + jJ''_{\frac{1}{2}n})$$
$$+2\alpha l\left[\tfrac{3}{4}J''_{\frac{1}{2}n} - \tfrac{1}{4}jH''_{\frac{1}{2}n} + \sum_{\substack{s=1 \\ (\neq \frac{1}{2}n'')}}^{\infty} \frac{J_s - 2jH_s s/n''}{1-(2s/n'')^2}\right] \ldots\ldots (17)$$

When αl is very small, the expression simplifies to

$$\Delta Z''_{AB} = \tfrac{1}{2}n''\pi(H''_{\frac{1}{2}n} + jJ''_{\frac{1}{2}n}) \quad \ldots\ldots\ldots (18)$$

From equation (17), we have for the short line

$$\Delta r''_{AB} = \tfrac{1}{2}n''\pi(1 - \alpha l)H''_{\frac{1}{2}n} + k_1 \quad \ldots\ldots\ldots (19)$$
$$\Delta x''_{AB} = \tfrac{1}{2}n''\pi(1 - \alpha l)J''_{\frac{1}{2}n} - k_2 \quad \ldots\ldots\ldots (20)$$

where

$$k_1 = 2\alpha l\left[\tfrac{1}{4}J''_{\frac{1}{2}n} + \sum_{\substack{s=1 \\ (\neq \frac{1}{2}n'')}}^{\infty} \frac{J_s}{1 - (2s/n'')^2}\right] \ldots\ldots\ldots (21)$$

$$k_2 = 2\alpha l\left[\tfrac{1}{4}H''_{\frac{1}{2}n} + \sum_{\substack{s=1 \\ (\neq \frac{1}{2}n'')}}^{\infty} \frac{2H_s s/n''}{1 - (2s/n'')^2}\right] \ldots\ldots\ldots (22)$$

The terms k_1, k_2, are generally small, but are not negligible at the higher frequencies. They may be eliminated by combining the deviations measured from the two ends of the line. When considered from the opposite end, the signs of the cosine terms J_s remain unchanged whereas the signs of the sine terms H_s are reversed.

Whence

$$\Delta r''_{BA} = -\tfrac{1}{2}n''\pi(1 - \alpha l)H''_{\frac{1}{2}n} + k_1 \quad \ldots\ldots (23)$$
$$\Delta x''_{BA} = \tfrac{1}{2}n''\pi(1 - \alpha l)J''_{\frac{1}{2}n} + k_2 \quad \ldots\ldots\ldots (24)$$

Thus

$$H''_{\frac{1}{2}n} = \frac{2\Delta r''_A}{n''\pi(1 - \alpha l)} \quad \ldots\ldots\ldots\ldots (25)$$

$$J''_{\frac{1}{2}n} = \frac{2\Delta x''_A}{n''\pi(1 - \alpha l)} \quad \ldots\ldots\ldots\ldots (26)$$

where

$$\Delta r''_A = \tfrac{1}{2}(\Delta r''_{AB} - \Delta r''_{BA}) \quad \ldots\ldots\ldots (27)$$
$$\Delta x''_A = \tfrac{1}{2}(\Delta x''_{AB} + \Delta x''_{BA}) \quad \ldots\ldots\ldots (28)$$

Equations (25) to (28) provide the means for obtaining the Fourier coefficients of a short line from the input-impedance deviations measured at the even resonance frequencies. Note also the relations between the impedance deviations measured from opposite ends of a short line, viz:

$$\Delta r''_{AB} = -\Delta r''_{BA} + 2k_1 \simeq -\Delta r''_{BA} \quad \ldots\ldots (29)$$
$$\Delta x''_{AB} = \Delta x''_{BA} - 2k_2 \simeq \Delta x''_{BA} \quad \ldots\ldots (30)$$

Input-impedance Deviations at Odd Resonant Frequencies

At odd resonance when $2\beta l = n'\pi$, we have

$$\Delta Z'_{AB} = \left\{1 + \exp(-2\alpha l)\right\}\sum_{s=1}^{\infty} \frac{J_s - 2jH_s s/n'}{1 - (2s/n')^2 - 4j\alpha l/n'\pi} \quad \ldots\ldots\ldots\ldots (31)$$

When αl is small

$$\Delta Z'_{AB} = 2(1 - \alpha l)\sum_{s=1}^{\infty} \frac{J_s - 2jH_s s/n'}{1 - (2s/n')^2} \quad \ldots\ldots (32)$$

Thus for the short line

$$\Delta r'_{AB} = \Delta r'_{BA} \quad \ldots\ldots\ldots\ldots (33)$$
$$\Delta x'_{AB} = -\Delta x'_{BA} \quad \ldots\ldots\ldots\ldots (34)$$

It is shown below that the input-impedance deviation can be readily measured at the even resonances, whereas the measurement at the odd resonances necessitates a special network. It may also be noted, however, that for a short line the input-impedance deviations at any odd resonance may be calculated from the values measured at the even resonances. Combining equations (25) and (26) with (32) we have, at the odd resonance n',

$$\Delta r'_{AB} = \sum_{n''=2,4,\ldots} M\Delta x''_{An} \quad \ldots\ldots\ldots\ldots (35)$$

$$\Delta x'_{AB} = \sum_{n''=2,4,\ldots} N\Delta r''_{An} \quad \ldots\ldots\ldots\ldots (36)$$

where

$$M = \frac{4n'^2}{n''\pi(n'^2 - n''^2)} \quad \ldots\ldots\ldots\ldots (37)$$

$$N = \frac{4n'}{\pi(n''^2 - n'^2)} \quad \ldots\ldots\ldots\ldots (38)$$

and $\Delta r''_{An} + j\Delta x''_{An}$ is the corrected input-impedance deviation at the even resonance n''. The factors M, N, are given in Table 1, and it will be seen that the number of terms required is not large, as the factors diminish rapidly when $n'' > n'$.

Measurements on Short Lines

Measurement of Input-impedance Deviations

By definition ΔZ is the difference between the input impedance and the mean impedance when the line is terminated by the mean impedance. Networks may be constructed which simulate the characteristic impedance of a given type of coaxial cable over a wide range of frequencies[14]; these contain a variable element which permits the network impedance to be adjusted to match the line under test, the mean impedance of the latter having been previously determined. With such networks ΔZ may be measured directly at any frequency. In the absence of such a network, ΔZ may be measured at the even resonant frequencies by Kaden's method[1]. In this the line is terminated with a fixed nominally non-reactive impedance Z_r approximately equal to the mean line impedance, which need not be accurately known. Kaden limited his measurements to the resistive component of ΔZ, but it is shown below that the reactive component can also be measured.

If δZ_{AB} is the input-impedance deviation with the line terminated by Z_r, then at even resonance we have from

equation (11)

$$\Delta Z''_{AB} = \delta Z''_{AB} + (Z_r - Z_m)\left\{1 - \exp(-2\alpha l)\right\} \ldots \quad (39)$$

When the line has small attenuation

$$\Delta Z''_{AB} = \delta Z''_{AB} + 2\alpha l(Z_r - Z_m) \quad \ldots\ldots \quad (40)$$

If the mismatch between line and termination is sufficiently small the second term may be neglected, and ΔZ is equal to the measured input-impedance deviation, i.e. to the difference between the input impedance and the impedance of the termination. If, however, $2\alpha l(Z_r - Z_m)$ cannot be neglected, it may be eliminated by measuring from opposite ends of the line. From equations (29) and (40) we have

$$\Delta r''_{AB} = \tfrac{1}{2}(\delta r''_{AB} - \delta r''_{BA}) + k_1 \quad \ldots\ldots \quad (41)$$

From equations (30) and (40)

$$\Delta x''_{AB} = \tfrac{1}{2}(\delta x''_{AB} + \delta x''_{BA}) + 2\alpha l(X_r - X_m) - k_2 \ldots\ldots \quad (42)$$

where X_r, X_m, are the reactive components of the termination and mean impedance respectively. Usually k_1, k_2, can be neglected and we have

$$\Delta r''_{AB} \simeq \Delta r''_{A} = \tfrac{1}{2}(\delta r''_{AB} - \delta r''_{BA}) \quad \ldots\ldots \quad (43)$$

$$\Delta x''_{AB} \simeq \Delta x''_{A} = \tfrac{1}{2}(\delta x''_{AB} + \delta x''_{BA}) + 2\alpha l(X_r - X_m) \quad .. \quad (44)$$

The input-impedance deviation is generally required as a measure of the internal irregularity of a drum-length, and the difference, if any, between $\Delta Z''_{AB}$ and $\Delta Z''_{A}$ is of no practical importance. It will be seen that the resistive component of the input-impedance deviation is obtainable directly from the measurements made at opposite ends of the line, but the reactive component has a small correction term $2\alpha l(X_r - X_m)$. The value of $X_r - X_m$ may be determined by measurement from both ends at the odd-resonance frequencies. In this case, for the short line

$$\Delta x'_{AB} = \delta x'_{AB} + 2(1 - \alpha l)(X_r - X_m)$$

and from equation (34) we have

$$X_r - X_m = -\frac{\delta x'_{AB} + \delta x'_{BA}}{4(1 - \alpha l)} \quad \ldots\ldots \quad (45)$$

The corresponding values of $X_r - X_m$ for the even-resonance frequencies are obtained by interpolation. For a given type of cable, X_m does not change appreciably with the small changes of modulus occurring from length to length in practice, and with a constant termination $X_r - X_m$ depends only on frequency; since the line-length is related to the resonant frequency, the correction factor

TABLE I

Factors Used in Calculating $\Delta Z'$ from $\Delta Z''$

$M = 4n'^2/n''\pi(n'^2 - n''^2)$

EVEN RESONANCE n''	ODD RESONANCE n'										
	1	3	5	7	9	11	13	15	17	19	21
2 ..	−·21	+1·15	+·76	+·69	+·67	+·66	+·65	+·65	+·65	+·64	+·64
4 ..	−·02	−·41	+·88	+·47	+·40	+·37	+·35	+·34	+·34	+·33	+·33
6 ..	−·01	−·07	−·48	+·80	+·38	+·30	+·27	+·25	+·24	+·24	+·23
8 ..	—	−·03	−·10	−·52	+·76	+·34	+·26	+·22	+·20	+·19	+·19
10 ..	—	−·01	−·04	−·12	−·54	+·73	+·31	+·23	+·19	+·18	+·16
12 ..	—	−·01	−·02	−·05	−·14	−·56	+·72	+·29	+·21	+·18	+·16
14 ..	—	—	−·01	−·03	−·06	−·15	−·57	+·70	+·28	+·20	+·16
16 ..	—	—	−·01	−·02	−·04	−·07	−·15	−·58	+·70	+·27	+·19
18 ..	—	—	−·01	−·01	−·02	−·04	−·08	−·16	−·58	+·69	+·27
20 ..	—	—	—	−·01	−·02	−·03	−·05	−·08	−·17	−·59	+·69
22 ..	—	—	—	−·01	−·01	−·02	−·03	−·05	−·09	−·17	−·59
24 ..	—	—	—	—	−·01	−·01	−·02	−·03	−·05	−·09	−·17
26 ..	—	—	—	—	−·01	−·01	−·02	−·02	−·04	−·06	−·09
28 ..	—	—	—	—	−·01	−·01	−·01	−·02	−·03	−·04	−·06
30 ..	—	—	—	—	—	−·01	−·01	−·01	−·02	−·03	−·04
32 ..	—	—	—	—	—	−·01	−·01	−·01	−·02	−·02	−·03
34 ..	—	—	—	—	—	—	−·01	−·01	−·01	−·02	−·02
36 ..	—	—	—	—	—	—	−·01	−·01	−·01	−·01	−·02
38 ..	—	—	—	—	—	—	—	−·01	−·01	−·01	−·01
40 ..	—	—	—	—	—	—	—	−·01	−·01	−·01	−·01

$N = 4n'/\pi(n''^2 - n'^2)$

EVEN RESONANCE n''	ODD RESONANCE n'										
	1	3	5	7	9	11	13	15	17	19	21
2 ..	+·42	−·76	−·30	−·20	−·15	−·12	−·10	−·09	−·08	−·07	−·06
4 ..	+·08	+·55	−·71	−·27	−·18	−·13	−·11	−·09	−·08	−·07	−·06
6 ..	+·04	+·14	+·58	−·69	−·25	−·16	−·12	−·10	−·09	−·07	−·07
8 ..	+·02	+·07	+·16	+·59	−·67	−·25	−·16	−·12	−·10	−·08	−·07
10 ..	+·01	+·04	+·08	+·17	+·60	−·67	−·24	−·15	−·11	−·09	−·08
12 ..	+·01	+·03	+·05	+·10	+·18	+·61	−·66	−·24	−·15	−·11	−·09
14 ..	+·01	+·02	+·04	+·06	+·10	+·19	+·61	−·66	−·23	−·15	−·11
16 ..	—	+·02	+·03	+·04	+·07	+·10	+·19	+·62	−·66	−·23	−·14
18 ..	—	+·01	+·02	+·03	+·05	+·07	+·11	+·19	+·62	−·65	−·23
20 ..	—	+·01	+·02	+·03	+·04	+·05	+·07	+·11	+·20	+·62	−·65
22 ..	—	+·01	+·01	+·02	+·03	+·04	+·05	+·07	+·11	+·20	+·62
24 ..	—	+·01	+·01	+·02	+·02	+·03	+·04	+·05	+·08	+·11	+·20
26 ..	—	+·01	+·01	+·01	+·02	+·03	+·03	+·04	+·06	+·08	+·11
28 ..	—	—	+·01	+·01	+·02	+·02	+·03	+·03	+·04	+·06	+·08
30 ..	—	—	+·01	+·01	+·01	+·02	+·02	+·03	+·04	+·04	+·06
32 ..	—	—	+·01	+·01	+·01	+·02	+·02	+·02	+·03	+·04	+·05
34 ..	—	—	+·01	+·01	+·01	+·01	+·02	+·02	+·02	+·03	+·04
36 ..	—	—	+·01	+·01	+·01	+·01	+·01	+·02	+·02	+·03	+·03
38 ..	—	—	—	+·01	+·01	+·01	+·01	+·02	+·02	+·02	+·03
40 ..	—	—	—	+·01	+·01	+·01	+·01	+·01	+·02	+·02	+·02

$2\alpha l(X_r - X_m)$ may be simply tabulated in terms of frequency and order of resonance.

Determination of Resonant Frequencies

The resonant frequencies are those for which $2\beta l = n\pi$, where n is an integer. They are conveniently measured by adjusting the frequency until the input impedance becomes non-reactive, the distant end of the line being open- or short-circuited. Errors arise due to the small reactive component in the characteristic impedance and to the presence of irregularities in the line. Considering the first of these, at resonance $\tanh\gamma l$ and $\coth\gamma l$ are wholly real, and for a uniform line,

$$Z_{op} = Z_m \coth \alpha l \quad \ldots\ldots (46)$$

$$Z_{sh} = Z_m \tanh \alpha l \quad \ldots\ldots (47)$$

Thus at resonance the angles of Z_{op} and Z_{sh} are equal to the angle of Z_m, i.e. ϕ_m. Let the frequency be shifted from f_n to $f_n + \delta f$ to make the input impedance non-reactive, and let the corresponding value of βl be $\frac{1}{2}n\pi + \theta$. Then, when n is odd,

$$Z'_{op} = Z_m \coth\left\{\alpha l + j(\tfrac{1}{2}n'\pi + \theta)\right\} = Z_m \tanh(\alpha l + j\theta).$$

Expanding by Taylor's theorem, we obtain for values of θ small compared with αl which is usually the case,

$$\tanh(\alpha l + j\theta) = \tanh \alpha l + \frac{\theta^2 \tanh \alpha l}{\cosh^2 \alpha l} + \frac{j\theta}{\cosh^2 \alpha l} \quad .. (48)$$

The phase-angle of $\tanh(\alpha l + j\theta)$ is thus $\dfrac{2\theta}{\cosh 2\alpha l}$.

The input impedance Z'_{op} is non-reactive when

$$\frac{2\theta}{\sinh 2\alpha l} = -\phi_m \quad \ldots\ldots (49)$$

It can be readily shown that for a line having small leakance and for which $\alpha \ll \beta$,

$$\phi_m = -\alpha/\beta \quad \ldots\ldots (50)$$

whence

$$\frac{2\theta}{\sinh \alpha l} = \alpha/\beta \quad \ldots\ldots (51)$$

Thus

$$\delta f'_{op} = f'_n \theta/\beta l = f'_n \frac{\sinh 2\alpha l}{2\alpha l}(\alpha/\beta)^2 \quad \ldots\ldots (52)$$

and when αl is small,

$$\delta f'_{op} = f'_n (\alpha/\beta)^2 \quad \ldots\ldots (53)$$

Similarly it can be shown that the frequency shift from true odd resonance to make Z'_{sh} non-reactive is $-f'_n(\alpha/\beta)^2$; in the same way we find that the frequency shift from true even resonance to make Z''_{op} non-reactive is $-f''_n(\alpha/\beta)^2$, and for Z''_{sh} it is $+f''_n(\alpha/\beta)^2$. Thus

$$\delta f_{sh} = -\delta f_{op} = (-1)^n f_n(\alpha/\beta)^2 \quad \ldots\ldots (54)$$

Since for high-frequency cables α is proportional to $f^{\frac{1}{2}}$ and β is proportional to f, δf is the same for all resonant frequencies, i.e. the error becomes relatively less as the frequency rises. To make the input impedance non-reactive the frequency is increased from true resonance when the input impedance is less than Z_m, and decreased when it is greater than Z_m.

For 104/375 coaxial cable, $\alpha = 0{\cdot}43 f_M^{\frac{1}{2}}$ nepers/mile, $\beta \simeq 34{\cdot}8 f_M$ radians/mile, whence $\delta f = 150$c/s. The small correction in this case may be readily applied, but usually it is negligible.

Considering now the effect of line irregularities, it has been shown elsewhere[13] that when these are small, they modify the open- and short-circuit impedances by a factor K_{AB}, given by

$$K_{AB} = 1 + \frac{p_{AB} + p_{BA}}{1 - \exp(-2\gamma l)} + \frac{p_{AB} - p_{BA}}{1 + \exp(-2\gamma l)} \quad (55)$$

When the attenuation is small, we have at even resonance, $1 + \exp(-2\gamma l) \simeq 2$, $1 - \exp(-2\gamma l) \simeq 2\alpha l$. From equations (29) and (30), $p''_{AB} + p''_{BA} \simeq j\Delta x''_{AB}/Z_m$, $p''_{AB} - p''_{BA} \simeq \Delta r''_{AB}/Z_m$. Thus

$$K''_{AB} = 1 + \frac{\Delta r''_{AB}}{2Z_m} + j\frac{\Delta x''_{AB}}{2\alpha l Z_m} \quad \ldots\ldots (56)$$

At odd resonance, $1 + \exp(-2\gamma l) \simeq 2\alpha l$; $1 - \exp(-2\gamma l) \simeq 2$; from equations (33) and (34), $p'_{AB} + p'_{BA} = \Delta r'_{AB}/Z_m$, $p'_{AB} - p'_{BA} = j\Delta x'_{AB}/Z_m$.

Whence

$$K'_{AB} = 1 + \frac{\Delta r'_{AB}}{2Z_m} + j\frac{\Delta x'_{AB}}{2\alpha l Z_m} \quad \ldots\ldots (57)$$

Hence the correction factor in terms of input-impedance deviations is the same for all resonant frequencies; we see that the irregularities alter the phase-angle by $\Delta x_{AB}/2\alpha l Z_m$, and necessitate an additional frequency shift

$$\Delta f_{op} = -\Delta f_{sh} = \frac{(-1)^n f_n \Delta x_{AB}}{n\pi Z_m} \quad \ldots\ldots (58)$$

For example, if $\Delta x_{AB} = 0{\cdot}1\Omega$, $Z_m = 75\Omega$, $f = 1$Mc/s, $n = 2$, then $\Delta f = 210$c/s.

Determination of Mean Impedance

The mean impedance Z_m plays such an important part in the theory of irregularities that its accurate measurement is a matter of prime interest, particularly for short lines. For this purpose, three methods are available, (i) by measurement of the input impedances with the distant end open and closed, (ii) by measurement of resonant frequencies and capacitance, and (iii) by comparison with a standard resistor at odd resonance.

Z_m from the Open- and Short-circuit Impedances

The characteristic impedance of a perfectly uniform line is given by

$$Z_m = \sqrt{(Z_{op} Z_{sh})} \quad \ldots\ldots (59)$$

Inasmuch as impedance measurement at high frequencies is most accurate when the phase-angle is zero, the tests are made at the "non-reactive" frequencies. From equations (56) and (57) it is seen that the line irregularities cause an error in the measurement of the modulus of Z_m equal to $\frac{1}{2}\Delta r_{AB}$. If the measurement is repeated from the opposite end of the line and the average taken, the error will cancel out at the even resonant frequencies, but will be unaffected at the odd resonances.

Z_m from Resonant Frequency and Capacitance

Since $|Z_m| = \sqrt{(L_u/C_u)}$ and $\beta = 2\pi f \sqrt{(L_u C_u)}$, we have

$$|Z_m| = \frac{\beta}{2\pi f C_u}$$

At the resonance frequencies, $2\beta l = n\pi$, whence

$$|Z_m| = \frac{n}{4 f C_u l} \quad \ldots\ldots (60)$$

The capacitance $C_u l$ is measured at low frequency, e.g. 1 000c/s, since with good quality dielectrics the change with frequency may be neglected. The resonant frequencies are determined from the frequencies at which Z_{op} or Z_{sh} is non-reactive, as discussed previously. From equations (55) and (60) we see that the error caused by the line irregularities is $\Delta x/n\pi$ ohms; as compared with the "open and closed" method, assuming that $\Delta r \simeq \Delta x$, the error is reduced by the factor $2/n\pi$.

Z_m by comparison with a Standard Resistor

If we measure the input-impedance deviation at odd resonance with the line terminated by a nominally non-reactive resistor $Z_r = R_r + jX_r$, we obtain $\delta r'_{AB}$ and from equation (11), since $R_m = |Z_m|$

$$|Z_m| = R_r + \frac{\delta r'_{AB} - \Delta r'_{AB}}{1 + \exp(-2\alpha l)} \quad \ldots\ldots (61)$$

We may calculate $\Delta r'_{AB}$ from the reactive components of the input-impedance deviations measured at the even resonant frequencies, using equation (35). However, with sufficiently regular lines and averaging the values obtained at two successive odd resonant frequencies, $\Delta r'_{AB}$ may be ignored.

It is probable that the accuracy of the resonant frequency-capacitance method is better than the accuracy of calibration of the standard resistor at the appropriate frequencies; in fact the best method of calibrating the resistor is to use equation (61) for a line with small irregularities whose mean impedance has been previously determined by the resonant frequency-capacitance method.

Measurement of Attenuation Coefficient

At the resonant frequencies, the attenuation coefficient is given by

$$\alpha l = \tanh^{-1} \sqrt{(R_{sh}/R_{op})} \text{ nepers} \quad \ldots\ldots\ldots \quad (62)$$

where R_{sh}, R_{op} are the real parts of Z_{sh}, Z_{op} respectively. When the irregularities are small, the error factor K_{AB} given by equation (55) cancels out, and the measured attenuation coefficient is free from error due to this cause. However, when working in the megacycle frequency range, difficulties arise in measuring both high and low resistances on the same type of bridge. The expedient is adopted with a bridge suitable for high impedances, of measuring Z_{op} at even resonances and Z_{sh} at odd resonances, using the value of $|Z_m|$ obtained by one of the methods described previously, together with the expression

$$\alpha l = \tanh^{-1}(|Z_m|/R) \text{ nepers} \quad \ldots\ldots\ldots \quad (63)$$

Similarly with a bridge suitable for low impedances, Z_{sh}

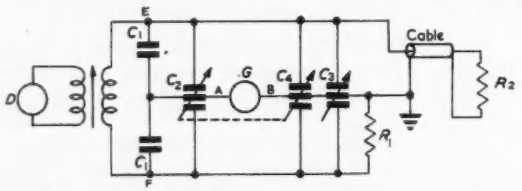


Fig. 2. Bridge for impedance measurements on coaxial cables

is measured at even resonances and Z_{op} at odd resonances, and the appropriate formula is

$$\alpha l = \tanh^{-1}(R/|Z_m|) \text{ nepers} \quad \ldots\ldots\ldots \quad (64)$$

In all these cases a proportional error of the order of $\Delta r/2Z_m$ occurs; however, with normal quality of 104/375 coaxial cable the error is well inside the limits of accuracy expected for attenuation measurements on short lengths.

Bridges for Impedance Measurement

A bridge for testing coaxial cables has been described by Fuchs and Fenouillet[8]; this contains fixed ratio arms, with variable inductors and resistors, and is used for the measurement of impedance irregularities and of attenuation by the "low-impedance" method over the frequency range of 0·06 to 10Mc/s. A bridge having variable capacitor ratio arms is employed by the British Post Office for tests on repeater sections of coaxial cable[9]; the principle has been adapted for measuring impedance deviations and attenuation by the "high-impedance" method on short lines up to 10Mc/s.

Referring to Fig. 2, the ratio arms consist of two equal fixed mica capacitors C_1 in parallel with a small differential air-capacitor C_2. As used for measuring irregularities, the cable under test is terminated by a resistor R_2 of about 75Ω, and is compared with a standard resistor R_1 of about the same value. The differential capacitor C_2 is calibrated to read the resistive component of the impedance deviation relative to the standard. The reactive component is measured by the differential air-capacitor C_3, calibrated in picofarads, δx being $2\pi f \times 75^2 \times \delta C_3$. The supply from a signal-generator G is fed across AB, and a communications receiver D, used as detector, is connected through a balanced and screened transformer across EF. A second balance is obtained with R_2 replacing the cable on the bridge, and the difference between the two sets of readings gives the input-impedance deviation with respect to R_2.

As used for measuring attenuation, the cable (open or closed at the far end according as the resonant frequency is even or odd) is connected to the bridge in parallel with a resistor R_3 of about 80Ω, and the frequency is varied until the reactance-capacitor reading is the same with the cable on and off the bridge. The change of ratio occasioned by disconnecting the cable tends to alter the reactance balance, but this effect is compensated by a small differential air-capacitor C_4 of appropriate value, ganged to C_2. The impedance of the cable is obtained from the difference r in the readings on the "resistance" dial with the cable on and off, and is given by $R_3(R_3/r - 1)$. For lower impedances, smaller resistances are used in place of R_3 and R_1, an appropriate correction being made to r for the change in the standard resistor, and the cable impedance may be tabulated in terms of r for each pair of resistors. The error introduced by C_4 in the measurement of impedance deviations is negligibly small.

References

1. Didlaukis, M., Kaden, H. Die Inneren Ungleichmäsigkeiten von Koaxialen Breitbandkabeln. *Elekt. Nachrichten-Technik. 14*, 13 (1937).
2. Merz, P., Pfleger, W. Irregularities in Broad-Band Wire Transmission Circuits. *Bell Syst. Tech. J. 16*, 541 (1937).
3. Brillouin, L. Irregularities in Telephone and Television Coaxial Cables. *Elect. Commun. 17*, 164 (1938).
4. Ville, J. Etude Statistique des Irrégularités des Câbles Coaxiaux. *Bull. Soc. Franç. Elect. 4*, 215, 253 (1944).
5. Cotte, M. Le Probleme du Trainage dans les Câbles de Télévision. *Bull. Soc. Franç. Elect. 5*, 107 (1945).
6. Cotte, M. La Détermination des Ecarts d'Impédance Locaux dans un Câble et de la Fonction de Corrélation de ces Ecarts. *Bull. Soc. Franç. Elect. 8*, 16 (1948).
7. Herreng, P., Ville, J. Etude des Irrégularités d'Impédance des Câbles, Coaxiaux par Observation Oscillographique des Echos d'une Impulsion. *Câbles et Transm. 2*, 111 and 219 (1948).
8. Fuchs, G., Fenouillet, P. Pont Haute Fréquence pour la Mesure des Ecarts d'Impédance. *Câbles et Transm. 4*, 126 (1950).
9. Taylor, R. E., Turner, R. J. Acceptance Testing of Coaxial Pairs for the Inland Trunk Network. *Post Off. Elect. Engrs.' J. 44*, 1 (1951).
10. Fuchs, G. Reflections in a Coaxial Cable due to Impedance Irregularities. *Proc. Instn. Elect. Engrs. 99*, Pt. IV, 121 (1952).
11. Halsey, R. J., Williams, H. The Birmingham-Manchester Holme-Moss Television Cable System. *Proc. Instn. Elect. Engrs. 99*, Pt. IIIA, 398 (1952).
12. Baguley, E., Cope, F. B. A Pulse Echo Test Set for the Quality Control and Maintenance of Impedance Uniformity of Coaxial Cables. *Post Off. Elect. Engrs.' J. 44*, 164 (1952).
13. Rosen, A. Irregular Transmission Lines. *Wireless Engr. 31*, 59 (1954).
14. Cheetham, R. S., Mather, E. L., Clarke, W. W. H. The Development of a Precision Termination for 0·375 in, Polythene-Disc Insulated Coaxial Cable. *Instn. Elect. Engrs.* Monograph No. 82 (1953).

UNDERWATER TELEVISION

One of the latest types of Marconi-Siebe, Gorman underwater television has recently been flown out to the scene of the Comet crash off Elba.

The camera differs from its predecessors in that it is fitted with a periscope lens which can "see" in any direction within a hemisphere; it being possible to rotate the lens, by remote control from the salvage ship, through an arc of 360°, it can also be elevated through 90°. It overcomes many of the difficulties of television underwater when weather conditions are poor and the apparatus is swinging with the tide, and allows the camera to scan a large area of the sea bed without having to move it either from above, or with the aid of a diver.

The new lens operates quite simply. The tube containing the lens arrangements passes through a brass plate inside the watertight pressure casing, which is fixed between the front of the camera and the viewing dome. The tube can rotate through a complete circle; its "eye"—the front portion—is pivoted to the tube and is able to elevate through 90°.

These movements are operated by servo-motors clamped to the brass plate and camera, and controlled by the operator on board by switches in his control unit. The unit is connected to the camera through the watertight camera cable.

A "fish bowl" viewing dome of inch-thick perspex now replaces the former window for viewing. This has the same refractive index as water so that it does not distort the image, and scratches on its surface are not shown on the monitor screens.

A Square Root-Law Circuit

By I. G. Baxter, B.Sc., A.R.C.S.

The output from a negative feedback amplifier is made proportional to the square root of the input, by means of a non-linear feedback network of resistors and miniature selenium rectifiers. The basis of the method is to generate a calibration curve made up of linear segments, which is very nearly parabolic.

THE circuit is being used as a corrector element in a blood flowmeter[1], in place of a system that depended upon the non-linear characteristics of a selected pentode valve[2]. Basically, it is a variable feedback amplifier; initially the feedback is small and the gain is correspondingly great, but when the output increases, consecutive increments of feedback progressively reduce the gain. The curve relating the input and output voltages (Fig. 1) is accordingly made up of linear segments which each inter-

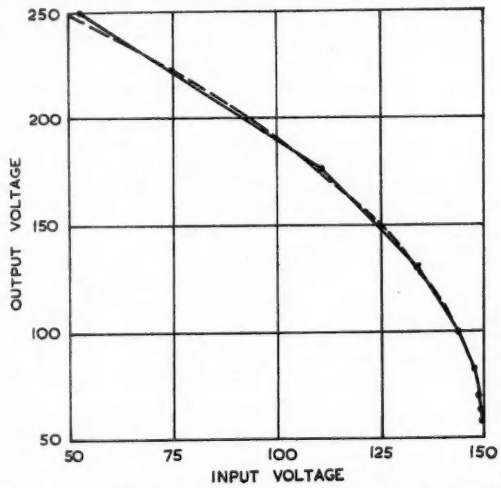


Fig. 1. Theoretical calibration curve composed of straight segments
The broken line represents an ideal parabola.

sect an ideal parabola at two points, resulting in error maxima at the points of inflexion and near the middle of each segment. It can be shown that if the percentage error regardless of sign is made the same at each point where it is greatest, then the points of inflexion or kinks will occur at output voltages which are related geometrically. There are seven kinks in the calibration of the present circuit (Table 1), the first being at 0·04 times peak output voltage. In theory, the greatest departure from a true parabola is 2½ per cent except in the region below the first kink, where the relative error increases rapidly. In practice, despite inaccurate setting up, and the behaviour of components falling short of the ideal, it has been found possible to keep errors well within 5 per cent except near the first kink.

In its general principles the system resembles one for squaring described by Marshall[3]. The chief differences in the present case are that the inverse operation is being performed, that miniature selenium rectifiers are used instead of germanium ones, and that the percentage error (not the absolute error) is made minimal.

Basic Circuit

A simple arrangement which should, in principle, fulfil the desired requirements is shown in Fig. 2. It comprises

TABLE 1
Calibration of Circuit
The input and output voltages at points of inflexion are tabulated, with corresponding values of gain.

INPUT VOLTAGE	OUTPUT VOLTAGE	GAIN
52·5	250·0	
		1·25
111·5	176·0	
		2·0
134·7	129·4	
		3·2
143·9	100·0	
		5·0
147·6	81·5	
		8·0
149·0	69·9	
		12·7
149·6	62·5	
		20·0
149·9	57·9	
		52·5
150·0	50·0	

an anode-follower in which the feedback network is made up of resistors and rectifiers. The input comes from the anode of a preceding stage. With a high input voltage the output is low and the potential at P is at or below earth,

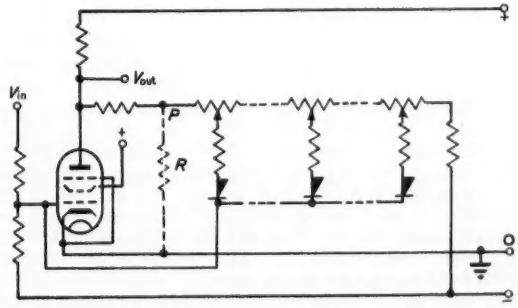


Fig. 2. Elementary square root law circuit

so that most (or all) of the rectifiers are non-conducting; feedback is slight and the gain high. When the input voltage falls, that at P rises with the increased output, and the rectifiers become conducting one after another, so increasing the feedback and diminishing the gain. Unfortunately, if non-thermionic rectifiers are used this scheme has shortcomings, and in any case it entails undesirably high values of feedback resistance.

It was desired to use type M-1 miniature selenium rectifiers, which are efficient, cheap and very small. They would be working in a moderately high impedance network, where their considerable forward resistance (about $10^4\Omega$) would be unimportant. Their measured backward resistance—at least in the batch tested— was much greater than the $20M\Omega$ specified by the makers, and quite adequate within a certain range of voltage. On the other hand, with reverse potentials

greater than about 25 to 30V they passed current significantly.

A large amplitude of output voltage (100V or more) is desirable, for ease of recording and to make the overall calibration less dependent on rectifier and valve characteristics. With the circuit in Fig. 2 this is incompatible with avoiding voltage overload of the rectifiers. Furthermore, at high gains the feedback resistance would be inconveniently high in itself, besides being of the same order as the aggregate shunt leakage path through the rectifiers. There are two objections to resolving these difficulties by providing a resistive connexion (R) to earth for reducing the excursion of potential at P. Firstly, variations in the switching voltage of the rectifiers assume greater importance, and secondly, under low gain conditions the feedback resistance becomes of a similar order to the forward resistance of the rectifiers.

Practical Circuit

The above considerations led to contriving a feedback network (Fig. 3) that is better matched to the rectifiers, and involves rational values of resistance. The arrangement is

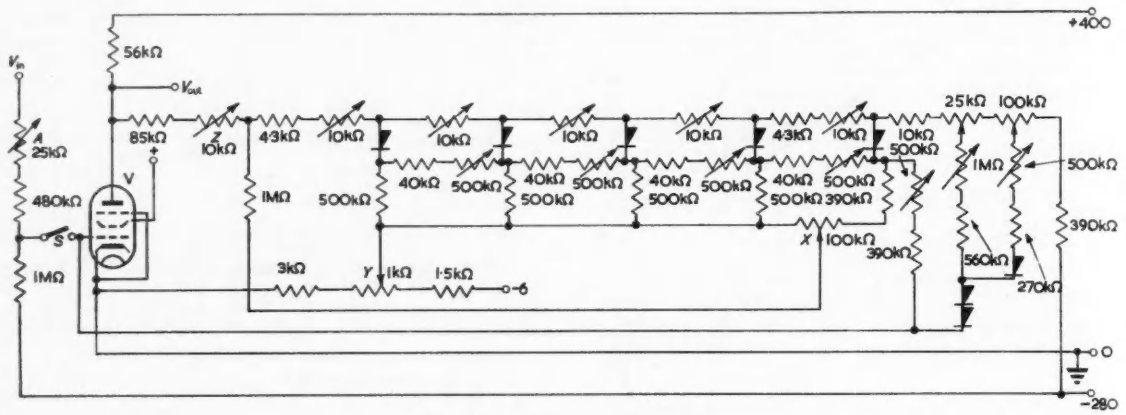


Fig. 3. Practical square root law circuit

essentially a ladder attenuator feeding the control grid of the amplifier valve, with each "rung" connected by a rectifier to the output potentiometer from the anode. When the output is low, only the rectifiers remotest from the grid are conducting, so feedback is slight and the gain high. An increase of output causes additional rectifiers to conduct, one by one, so that feedback is injected closer to the grid and the gain is diminished. Under conditions of high gain the rate of change of voltage across a rectifier approaching conduction is not seriously less than that at the output itself, and this is conducive to accurate switching in the region where it is most needed. As each rectifier cuts in, so does the voltage across the next one change less rapidly in relation to the output, owing to the additional current in the network; the adverse effect of this on switching accuracy matters little when related to the rise in output.

It was found impracticable to use the ladder network for feedback over the whole operating range, because this would have entailed inconvenient values of resistance. The two final increments of feedback, therefore, take place through direct routes to the grid. To avoid voltage overload of the rectifiers concerned, two units in series are used in the penultimate path, and to the ingoing side of this pair is connected the rectifier for the final path.

The initial gain, with all the rectifiers non-conducting, is governed by a connexion from the output potentiometer to a tapping on the first "rung" of the ladder. Grid bias is provided by connecting one side of the ladder to a potentiometer that gives the required reference potential. This potentiometer, with the valve heaters, is fed from a battery to ensure stability. Regulated H.T. and negative supplies are used.

The effective anode load falls as the rectifiers successively conduct, but this is no drawback because it occurs in harmony with the desired decrease of gain. Maximum gain is conveniently required when the anode current is highest and the g_m large.

Setting Up

The resistances were calculated approximately, and the circuit was then built; numerous variable resistors were included so that the calibration could be adjusted experimentally, both as regards the slope of each linear segment and as to positioning of the points of inflexion. Permanently wired in series with each rectifier was a 100Ω resistor, across which a galvanometer could be shunted as a switching indicator when making adjustments.

Calibration was carried out on a straightforward but tedious trial and error basis. The points of inflexion and the gains were set, respectively, by adjusting the tapping points on the output potentiometer, and the variable resistors in the ladder network. In was necessary to work upwards from the condition of lowest gain, to minimize the disturbance of one setting by the next. Even so, the sequence of adjustment had to be repeated once or twice before the correct calibration was attained.

The origin was fixed in the following way. Switch S was opened, and potentiometer X set to minimum. Potentiometer Y was then adjusted to make the output meter read correctly, after which potentiometer Z was set so that this reading was not altered by traversing X over its full range. Lastly, with the input voltage at the desired initial value, switch S was closed, and potentiometer A adjusted to restore the correct output reading.

Conclusion

The circuit fulfils the requirements it was designed for, at the cost of a large number of fixed and variable resistors. Any appreciable improvement in performance is barred by instability of the components and by the great gain needed near the origin. As it is, origin drift does occur, but this is not objectionable in the present application because there are opportunities for checking, and there is ample input signal most of the time.

If a lower order of accuracy were acceptable, there could be fewer feedback steps, less accurately graded, and it would be possible to use a smaller proportion of variable resistors.

For example, for the computed maximum error to be within 5 per cent from the first kink upwards, five changes of gain would be adequate. For an error of 10 per cent, three kinks would suffice.

The advantages of the system are that it is not dependent upon discovering a single circuit element, such as a pentode valve, that has the desired non-linear characteristics, and it can be adjusted if necessary, to suit curves that are not parabolic.

REFERENCES

1. Baxter, I. G., Pearce, J. W. Simultaneous Measurement of Pulmonary Arterial Flow and Pressure Using Condenser Manometers. *J. Physiol. 115*, 410 (1951).
2. Baxter, I. G. An Electrical Flowmeter for Recording Blood Flow. *Electronic Engng. 24*, 162 (1952).
3. Marshall, B. O. (Jr.). An Analogue Multiplier. *Nature, 167*, 30 (1951).

Maintaining Optimum Cycling Intervals in a Two-step Controller

By W. R. Beakley,* M.A., Ph.D.

THE simplest type of automatic temperature control system uses two-step action to regulate the process. With this type of control oscillation about the desired value continuously occurs, but the amplitude of the oscillation may be reduced to a very small value by replacing a large part of the controlled power with a source of constant auxiliary power. Optimum working conditions exist when the on and off parts of the control cycle are approximately equal. Changes in load cause the duration of one or other part of the cycle to increase. In practice an increase in duration of either part of the cycle by a factor of up to 4 compared with the optimum duration still ensures effective control. Control is lost whenever a change in load occurs which is greater than the controlled power, or when large random variations occur in the auxiliary power. When these changes are slow this difficulty may be overcome by controlling the auxiliary power in steps of rather smaller magnitude than that of the primary controlled power. The instrument to be described does this by responding when the duration of the on or off periods exceeds a pre-set value and by remaining inert when the controller is acting effectively.

Fig. 1 is a circuit diagram of the instrument. The rectified output from the switch contacts of the two-step controller actuates the relay *A*. This relay substitutes C_1 for C_2, discharging the one and connecting the other (C_1 say) between anode and grid of the Miller integrator V_1. As this capacitor charges, the anode voltage of V_1 rises and unless relay *A* again interchanges the capacitors, it reaches the voltage of the cathode of V_{2a} in a time t given approximately by:

$$t = \frac{CR\ V_c}{V_b}$$

where C is the capacitance of C_1 or C_2, R is the resistance of the grid leak, V_c the voltage at the cathode of V_{2a} and V_b is the bias voltage. Here $t = 10CR$.

When V_{2a} conducts the Miller action ceases and the grid of V_1 is allowed to fall comparatively rapidly, cutting off the screen current and releasing relay *B*. The contact B_2 opens and allows C_4 to discharge through the selected resistor R_4 to R_9; the time-constant of these components governs the time for which V_1 is cut off. During this part of the cycle C_1 is discharged via the contact B_1, while the control motor is switched on and runs in the direction set by the state of relay *A*. When the voltage at the grid of V_1 rises through cut-off, relay *B* is again energized, charging C_4 and replacing C_1 between anode and grid of V_1; the initial surge of charging current of C_1 prevents V_1 being again cut off as the full bias voltage is restored. The circuit is now in its original condition.

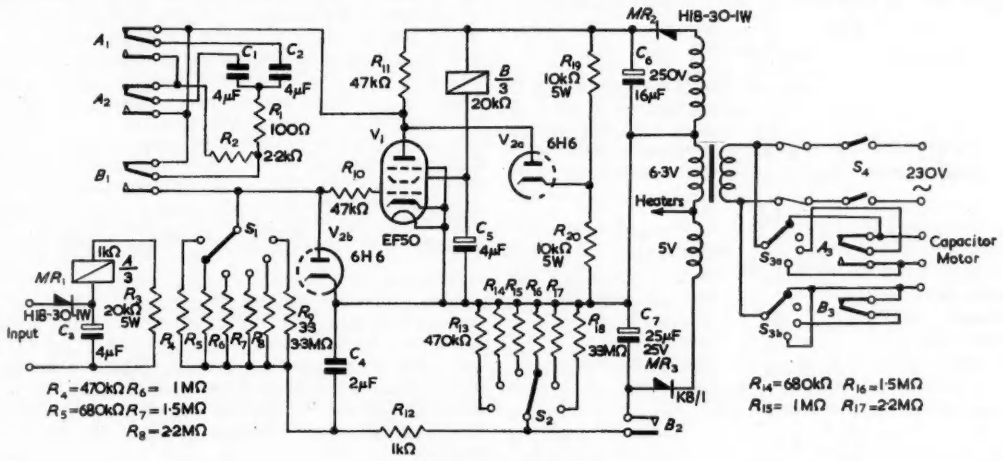


Fig. 1. Circuit of the controller

The diode V_{2b} prevents V_1 passing excessive grid current at the moment when C_1 or C_2 is connected between anode and grid.

Should the two-step controller change its state before the anode voltage of V_1 reaches the cathode voltage of V_{2a} the circuit is reset by relay *A* without operation of relay *B*.

The switch S_3 is included to allow the auxiliary power to be set manually when required.

This instrument has given trouble-free service controlling conditions in the large-animal psychrometric chamber at this Institute, for a total of 7 000-8 000 hours, during which time it has operated over a large number of periods of a few days each, and also continuously over periods of one to three months.

* *The Hannah Dairy Research Institute, Kirkhill, Ayr.*

The Measurement of Very Small Direct Currents

By M. W. Jervis*, B.Sc.Tech., A.M.I.E.E.

The necessity for measuring direct currents in the range of $1\mu A$ to $10^{-16}A$ arises in many branches of physics and engineering. This article is a review of the methods used, particular attention being paid to the thermionic and capacitor modulator electrometers.
Reference is made to the factors limiting accuracy and sensitivity obtainable by the methods described, together with some notes on the precautions necessary when measuring very small currents.

THE necessity for measuring small currents arises in many branches of physics and usually amounts to the determination of the rate of flow of free charged particles. One ampere corresponds to 6 by 10^{18} electrons per second and currents as low as 6 electrons per second have been detected.

Fig. 1 indicates the range of currents to be discussed.

Typical examples occur in the field of vacuum physics where ion currents of 10^{-7}A ($0{\cdot}1\mu$A) are measured in ionization vacuum gauges and 10^{-14}A in mass spectrometers. In the determination of X-ray and nuclear radiation by ionization chambers, the measurement of currents as low as 10^{-16}A is required[1].

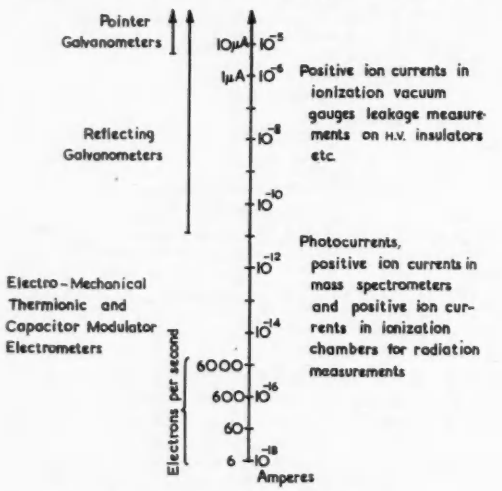


Fig. 1. The range of currents discussed

Common Types of Current Measuring Instruments

Galvanometers

The moving-coil pointer indicating instrument is the most common current measuring device and microammeters are available to read about 10μA full-scale. For smaller currents, galvanometers are used in which a beam of light replaces the pointer. These are available with sensitivities of about 10^{-11}A/mm deflexion[2] on a scale placed 1 metre from the instrument.

A galvanometer of such sensitivity is a delicate laboratory instrument and great precautions must be taken to avoid movement of the spot due to vibration, draughts, etc. Even when these effects have been removed, residual fluctuations remain. These fluctuations arise partly from rotation of the coil caused by its bombardment by air molecules (Brownian motion) and partly from the thermal agitation voltage generated in the resistance of the instrument and circuit. The fluctuations, or "noise" as they are called, cause the mirror of the galvanometer to be in continuous movement, corresponding to about 10^{-12}A at room temperature, so that they impose this definite limit on the smallest current which can be detected[2].

Galvanometer Amplifiers

In galvanometer amplifiers, the light spot reflected from the galvanometer is made to fall on a photocell instead of a scale. The photocell is usually split into two and may be of photo-voltaic or photo-emission type. The former will usually operate a secondary less sensitive galvanometer directly[3], while the latter is followed by a thermionic valve amplifier[4]. Such an arrangement gives the effect of a very long optical pointer and the amplifier can be made with a large output for automatic pen recording. In both cases, negative feedback is often applied, as this gives a convenient sensitivity control and improves linearity, response time and permanency of calibration. It can be seen that the Brownian movement limitation remains, however, though the system is a convenient one to use[4].

Other Low Resistance Devices

The equivalent voltage fluctuations arising in devices such as magnetic and contact modulator amplifiers can be made very small[5].

In the most stable magnetic amplifiers, the input instability is about 2μA-turns[6]. The number of turns is, however, limited by the winding space and smallest convenient gauge of wire and, in practice, the noise amounts to about 10^{-12}A.

With the contact modulator amplifier[5], the input noise expressed as a voltage can be made small, but the maximum input resistance which can be used is restricted to a value which does not result in excessive pick-up from the driving coil. A further limitation on the maximum input resistance is set by the requirement that the input time-constant must be small compared with the time during which the contact is in the open or closed position. If this condition is not satisfied, the recorded voltage will depend on the closed and open time of the contactor. These conditions make contact modulators more suitable for measuring voltages than currents, though they have been made[7] with an input noise of 10^{-12}A. Using a specially screened contact modulator, Kroebel[8] reports noise of $2{\cdot}5\mu$V across impedances of $10^8\Omega$ for a 1c/s bandwidth.

Low resistance measuring instruments have the advantage of requiring a small voltage drop across them, but, in most cases, a high impedance can be satisfactorily used.

Measurement of Smaller Currents

Electrometers

The smallest detectable current with available galvanometers[2] is limited by Brownian movement to about 10^{-12}A. Much smaller currents can be measured by electrostatic

* *Research Laboratory, Associated Electrical Industries Ltd.*

devices, though these require a relatively high voltage drop.

There are two ways in which such high impedance electrometer type devices can be used:

Voltage Drop Method

The current I to be measured is passed through a high resistor R and the electrometer used to measure the voltage drop V across it (Fig. 2). Then:

$$I = V/R \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

e.g. $I = 10^{-15}$ A, $R = 10^{12}\Omega$, $V = 1$mV.

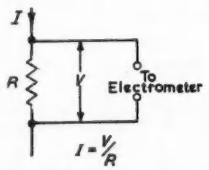


Fig. 2. Voltage drop method

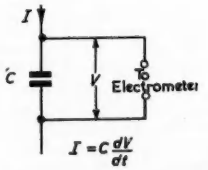


Fig. 3. Capacitor charging method.

Capacitor Charging Method

The current I is measured by the rate of rise of voltage across a capacitor C (Fig. 3) then:

$$I = C\,dV/dt \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

e.g. $I = 10^{-15}$A, $C = 10$pF, $dV/dt = 100\mu$V/sec.

The leakage resistance must be very high for the charging rate to be constant in the capacitor charging method. This method determines the average current over the time taken for the measurement and so is not suitable for varying currents. The voltage drop method can be used for varying currents only when the rate of change of current is small compared with $1/RC$, where C is now the stray capacitance of the input circuit.

Both voltage drop and capacitor charging methods can be used as a null method, so improving the accuracy and eliminating errors due to changes in electrometer sensitivity.

Limitations of Accuracy

COMPONENT AND INSTRUMENTAL LIMITATIONS

It can be seen that the accuracy of measurement will be no better than that to which the resistor or capacitor is known, but when very small currents are being measured, the major factor limiting accuracy and sensitivity is instability of the electrometer zero in the form of slow drifts or random fluctuations.

The zero fluctuations may be instrumental in origin and therefore characteristic of the type of electrometer. These will be discussed in the section appropriate to the various electrometer types.

There is also one source of noise due to thermal agitation, which is common to all electrometers.

THERMAL AGITATION NOISE

Whether the voltage drop or capacitor charging method is used there will always be some resistance and capacitance of the electrometer and the effective circuit will be as in Fig. 4.

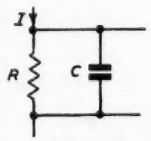


Fig. 4. Effective circuit of electrometer

It can be shown[5] that the thermal agitation voltage E_n across such a circuit is given by $E_n^2 = kT/C$ provided the bandwidth is limited by R and C only; k is Boltzmann's constant and T the temperature in degrees Kelvin.

In the case of the voltage drop method, the signal voltage $E_s = IR$. It can be shown[5] that the peak-to-peak fluctuations of voltage are about eight times the R.M.S. value, so that the smallest current which can be detected with certainty is given by:

$$IR = 8E_n = 8\sqrt{(kT/C)} \therefore I = \frac{8}{R}\sqrt{(kT/C)} \quad \ldots\ldots \quad (3)$$

e.g. for $T = 300$°K (27°C), $C = 9$pF, $R = 10^{12}\Omega$, $I = 8/10^{12} \times \frac{64 \times 10^{-6}}{3} = 2 \times 10^{-16}$A, or about 100 electrons/sec.

For 5 per cent accuracy, the time taken for the measurement will be $3CR$, i.e. 27sec.

In the limiting case when R is made infinite, the current is measured by the capacitance charging method. Assuming that the current I to be measured is constant, the signal voltage E_s after a time t is given by equation (2), i.e.

$$E_s = It/C$$

Therefore, the minimum detectable current for $t = 27$sec (as in above example) is given by:

$$It/C = 8\sqrt{(kT/C)} \therefore I = \frac{8}{t}\sqrt{(kTC)} \quad \ldots\ldots \quad (4)$$

For $C = 9$pF, $T = 300$°K, $I = \frac{8 \times 9 \times 10^{-12}}{27} \times .20 \times 10^{-6} = 6 \times 10^{-17}$A.

OTHER SOURCES OF NOISE

It should be emphasized that the considerations of the last section concern the limit of the smallest detectable current set by thermal agitation noise. In practice, instrumental difficulties prevent this limit being reached except in cases where great precautions are taken (Appendix 1).

An example of this is the noise generated by the passage of current in the semi-conductor material of which high valued resistors are constructed[9]. This noise can become important in some measurements when using the voltage drop method, but it is being reduced by better manufacturing processes and materials.

TIME NECESSARY TO MEASURE A GIVEN CURRENT

In the case of the capacitor charging method, the time necessary to detect a given current is given directly from equation (4), i.e.:

$$t = \frac{8}{I}\sqrt{(kTC)} \quad \ldots\ldots\ldots\ldots \quad (5)$$

The time necessary to measure a current to a given accuracy is many times that required to detect it (given by equation (5)) and the time increases as the accuracy required increases.

For the voltage drop method with capacitance present, the voltage across them will follow an exponential law of time-constant RC. For the voltage to reach 95 per cent of its final value, a time $3RC$ must elapse after the start of the measurements, e.g. $R = 10^{12}\Omega$, $C = 9$pF, $3RC = 27$sec. From equation (3) it can be seen that R must be large to measure a small current and therefore, for a given capacitance C, the measurement time will also be long. In practice, the maximum time available is limited by zero drift of the electrometer.

The effective time-constant can be reduced by the application of negative feedback (Appendix 2).

STATISTICAL ERRORS

If the current measured consists of the passage of n randomly spaced discrete charges, the standard deviation in the number measured is $\sqrt{n}$. In practice, the error caused by thermal agitation necessitates the collection of such a large number of charges that statistical errors are small[10,11].

Practical Instruments

ELECTROMECHANICAL ELECTROSCOPES AND ELECTROMETERS

In a review of electroscopes and electrometers, Neher[10] defines the difference between them as follows—"electro-

scopes need only one potential for their operation, while electrometers require auxiliary potentials." An example of an electroscope is the familiar simple gold leaf electroscope while electrometers are generally more refined instruments.

Electroscopes are usually characterized by simplicity, portability and low cost, and since they require no auxiliary potentials for their operation, there is no instability due to supply voltage fluctuations. They are, in general, less sensitive than electrometers, and are not easily used in a null method of reading, but they have considerable application as portable detectors of nuclear particles and radiation[1].

Numerous electrometers are described in the literature[1,2,10]. The most sensitive are the Dolezalek, Compton and Hoffmann types. The latter can be made with a capacitance of 3pF and a charge sensitivity of $1{\cdot}5 \times 10^{-16}$ coulombs/scale division. This enables a current of one electron per second (about 10^{-19}A) to be registered with a 15-minute measuring time. These instruments require considerable skill in setting up and are not portable. A more convenient and portable instrument is the Lindemann electrometer which has a needle which can be viewed

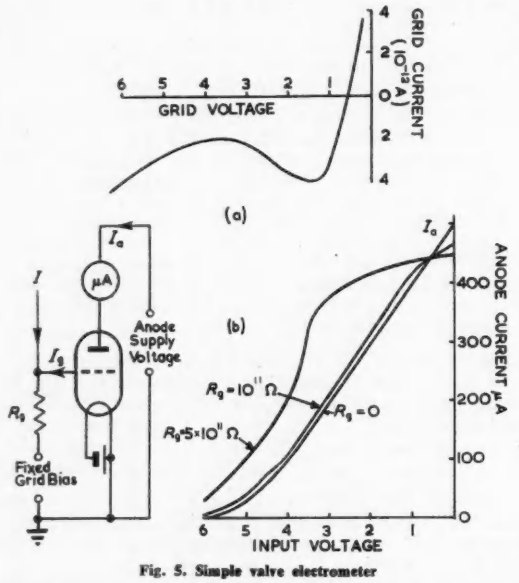


Fig. 5. Simple valve electrometer

through a microscope and gives a sensitivity about twenty times less than the Hoffmann instrument.

Feedback can be applied to some electrometers by a light beam and photocell in a similar manner to galvanometers. This enables air damping to be replaced by electrical damping, the instrument being evacuated[12]. This reduces fluctuations arising from collision of air molecules with the electrometer system and enables smaller currents to be measured. By using this arrangement with a specially designed electrometer, Milatz et al[12] suggests that the R.M.S. error in charge can be reduced to 8 or 9 electrons for a measuring time of 10 seconds.

Thermionic Electrometers

The desirable properties of an electrometer, i.e. high input resistance and low input capacitance, can be obtained with a thermionic valve.

When a current is to be measured by a valve, fluctuations in the current taken by the measuring electrode, the control grid, must be small compared with the current being measured. Fluctuations in the control grid current occur because of valve electrode potential changes, variations in cathode emission, contact potential changes, shot noise, etc. Also, since the grid current in general varies with control

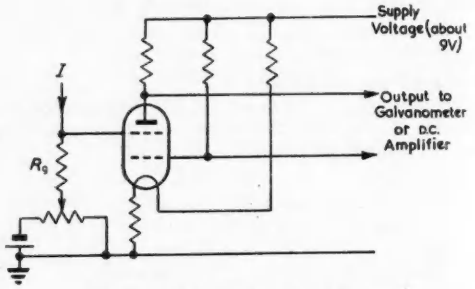


Fig 6. DuBridge and Brown Circuit

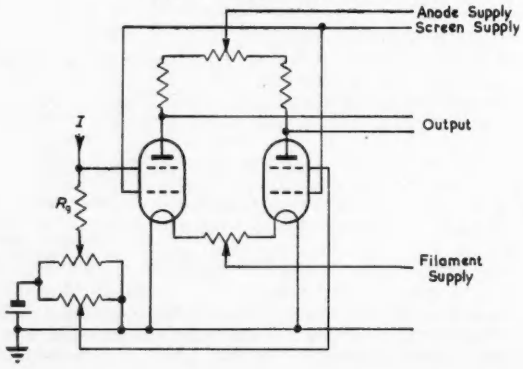
grid potentials (Fig. 5(a)), non-linearity of the relationship between signal current and grid potential may result when large values of grid resistors are used (Fig. 5(b)). For these reasons, "electrometer" valves with small grid currents were developed[13] for measuring very small currents. One popular tetrode electrometer valve has a grid current of only 10^{-16} to 10^{-17}A.

In general, the large grid current of ordinary receiving valves makes them unsuitable for electrometer service. Some valve types, when operated under certain conditions, can be made to operate with grid currents of 10^{-14} to 10^{-15}A. Although such results can be obtained with some specimens of a given valve type, considerable selection is usually necessary[14,15,16].

In the case of tetrode valves, zero drift due to supply voltage variations can be reduced by the DuBridge and Brown[5,9] type of circuit, shown in Fig. 6. In this arrangement, supply voltage variations cause almost equal changes in screen grid and anode current so that their difference remains constant for a constant control grid voltage. Many modifications have been described giving varying degrees of compensation against zero instability[9,17] caused by supply voltage variations.

Two valves can be used in the bridge arrangement[18], illustrated in Fig. 7, so that supply voltage changes have very little effect on the out-of-balance current, since the bridge arms are symmetrical. The two valves in such circuits may be replaced by two valves built into a common envelope with common cathode and space charge grid[19,20] (Fig. 8). If the two sections have characteristics which can be compensated by adjustment of the circuit constants, the effect of supply voltage variations and internal valve changes can be greatly reduced, a zero stability referred to the input of 100μV/hr being possible. The difficulties of precise and stable adjustment of the compensating components make it necessary to use high capacity accumulators or well stabilized mains operated supplies when making very sensitive measurements[20,21].

Fig. 7. Balanced bridge circuit



Although disturbances due to external causes are reduced by balanced circuits, internal fluctuations in the valves, e.g. flicker effect, cause a greater noise level than in single valve circuits. Flicker effect is a source of noise originating from the cathode and becomes important at low frequencies[22]. Tests on noise and grid current in valves[23] show that for non-electrometer valves, the grid current noise greatly exceeds flicker noise. In electrometer valves with grid currents of the order of 10^{-15}A, flicker noise is often more serious than the shot noise of the grid current.

When used under low grid current conditions, electrometer valves in general have a mutual conductance of about 50μA/V, which is small compared with ordinary valves. The electrometer valve can be operated with a grid resistor of $10^{12}\Omega$, however, and if a current of 10^{-15}A is passed through this resistor the anode current will be changed by 0·05μA. Such a current is easily detected by a reflecting galvanometer. It is interesting to note that a current amplification of 50 million is obtained in one valve.

As an alternative to using the electrometer valve as a current amplifier, it can be used as a voltage amplifying stage, the output being fed into a D.C. amplifier. Since the

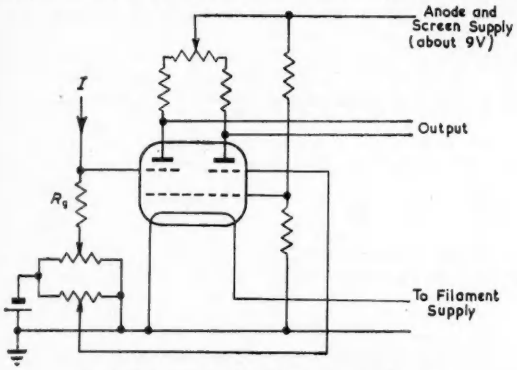


Fig. 8. Balanced tetrode circuit using double valve

voltage amplification of electrometer valves is small, usually about unity, the drift and noise introduced by the subsequent amplifier must be less than that due to the electrometer valve if the latter is to be used to its full capacity. The D.C. amplifier can be made capable of a large power output, so enabling automatic pen recording of small currents. If negative feedback is applied, it can be used to give constant and controllable gain (Appendix 2), this being required in mass spectrometer amplifiers.

Multi-stage D.C. amplifiers are usually used where high gain is required and many circuits have been described. Some of these have highly critical adjustments for best performance and if the adjustments drift for any reason, the performance suffers. The balanced type with a well stabilized power unit, such as that described by Peirson[24], is likely to give the best results over long periods without adjustment. In general, the zero instability of thermionic D.C. amplifiers (referred to the input) will not be less than 50-100μV (drift + noise) over 30min[22]. An extensive review of various types of D.C. amplifiers is given by Kessler[25].

A convenient arrangement, which has been used by Chance and Legallais[26], is to follow the electrometer valve with a low drift contact modulated amplifier. Alternatively, magnetic or galvanometer amplifiers could be used. Instead of D.C. amplification, electrometer tetrode valves have been employed as D.C. to A.C. convertors by applying suitable modulation to the control grid and the signal to the screen grid[27]. This modulator is followed by an A.C. amplifier and demodulator. The arrangement has some of the advantages of the capacitance modulator system and can be made with a zero stability of 0·5mV in 24 hours and a grid current of 10^{-14}A[28]. None of these possibilities appear to have been much exploited, however.

As with other types of electrometer, a steady drift is not necessarily serious and for quick measurements, it is the noise which sets a limit to the accuracy obtained. If precautions are taken to remove other sources of instability, the performance of thermionic electrometers will be limited mainly by shot effect of the grid current. Though the algebraic sum of grid current components (positive and negative) is small or zero, each component exhibits its own shot noise. The capacitance charging method is used for very sensitive measurements and currents of 5×10^{-18}A have been detected by this means[21]. Currents of the order of 10^{-16}A can be detected with the voltage drop method, though 10^{-15} is a value nearer that obtained in routine work.

Capacitance Modulator Electrometers

In these devices[5], the direct current to be measured is made to charge a capacitor, C_v in Fig. 9, the value of which is periodically varied, so giving rise to an alternating voltage which is then amplified. The voltage generated

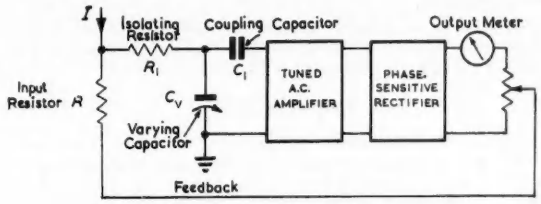


Fig. 9. Capacitance modulator electrometer

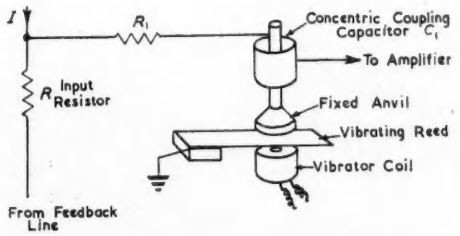


Fig. 10. Principle of vibrating reed electrometer

across capacitor C_v is taken through an isolating capacitor C_1 before being passed into the amplifier. In one design, illustrated in Fig. 10, the capacitor C_v is formed by the capacitance between an insulated fixed anvil and an earthed vibrating reed.

The use of A.C. amplification represents a great simplification compared with D.C. throughout. The bandwidth of the A.C. amplifier can be made small and centred on a frequency away from that contained in interference (such as 50c/s, microphony, etc.) and out of the range where flicker effect is troublesome and enables the theoretical limit set by thermal agitation to be more nearly approached.

The high gain A.C. amplifier is followed by a phase sensitive detector, D.C. feedback being applied (Fig. 10) to maintain constant and controllable sensitivity and reduce the input time-constant (Appendix 2).

Although the A.C. amplifier removes the difficulty of drift experienced with D.C. amplifiers, zero drift can originate from contact potential changes between the capacitor modulator electrodes. By paying attention to the treatment of the parts to keep the contact potentials constant, the drift referred to the input can be reduced to 0·1 to 1mV/day[29,30].

This type of electrometer requires considerable mechanical precision and special treatment of the capacitor electrodes, but the instrument is a very convenient and robust device and is not easily damaged by electrical overload.

Conclusions

The performance of all three types of electrometer described can be made to approach that fixed by thermal agitation noise, provided precautions are taken to remove instrumental limitations.

The electro-mechanical electrometers have the disadvantage of fragility and difficulty of setting up, though some types, such as the Lindemann, have the virtue of small size and relative simplicity.

The thermionic valve electrometers are more convenient to use. If no subsequent amplifier is used, a very sensitive galvanometer is necessary when measuring very small currents. D.C. amplification after an electrometer valve gives greater power output for automatic recording purposes, but often introduces considerable noise and zero drift, though these can be much reduced by choice of a suitable amplifier.

The capacitor modulator is superior to the other types, being very sensitive and at the same time robust and reliable.

Acknowledgments

The author is indebted to his colleagues for helpful discussion and criticism and to Dr. T. E. Allibone, F.R.S., for permission to publish this article.

Appendix 1.

General Experimental Techniques

To reduce leakage currents, insulators supporting the input conductor to an electrometer must be of high resistance. It is also desirable to surround such terminals with a guard ring maintained at the potential of the conductor supported. Electrometer valves are usually fitted with external and internal guard rings[19].

As a high insulation material, polished amber has been much used, but nowadays plastic insulating materials such as polished polystyrene, polythene and polytetrafluorethylene (P.T.F.E.) are often employed. These have the advantage of being able to be moulded, and P.T.F.E. that of having a higher working temperature and rigidity, though more expensive. Fused quartz is a good insulator, though care must be taken to ensure that it is free from piezo electric charges caused by strain. Glass is relied upon in electrometer valves for the input terminal insulation, but it has been known to exhibit polarization effects. The effective surface resistivity of glass and ceramic materials under humid conditions can be increased by the use of waxes or silicone varnishes[16]. For measuring the smallest currents, it is preferable to avoid leakage due to moisture by enclosing the electrometer valve in an evacuated enclosure. The enclosing vessel can conveniently be made an electrical screen and serve to screen the valve from light, as this increases the grid current because of the photo-electric effect on the electrodes, and if variable in intensity, leads to spurious signals.

Screening from both static and alternating electric fields is very important. Alternating voltages induced by magnetic fields can be reduced by keeping loops in the wiring as small as possible. Stray alternating voltages are to be avoided since they can be rectified by non-linearity in the electrometer, so giving a spurious indication[11,18]. The disturbing effect of spark coils, switch contacts in inductive circuits, etc., can be reduced by filters in the leads to the electrometer electrodes.

It is recommended that unnecessary insulation should be coated with a conducting material such as colloidal graphite in order to avoid the accumulation of static charges.

Essential insulation should be screened from varying potentials for the same reason. Currents as high as 10^{-12}A can be caused by very slight movements of concentric flexible cables connected to the input of electrometers. These currents are caused by charges formed on the outer surface of the insulated core of the cable and can be prevented by coating this with graphite. When measuring currents of less than 10^{-13}A, long term fluctuations caused by recovery of insulation from previous mechanical shock or compression may occur.

In the past, investigators have made their own high valued resistors, but now commercially produced units are available with values up to $10^{13}\Omega$. The semi-conducting nature of these resistors gives rise to rather a high temperature coefficient of resistance and poor stability over long periods, so limiting the accuracy[1]. The best resistors are stable to a few per cent over periods of months and have a temperature coefficient of 0·2 to 0·4 per cent/°C[21].

Appendix 2.

Use of Negative Feedback with Electrometers

If an electrometer is followed by an amplifier gain $-A$, negative feedback can be applied through a potential divider ratio β to the earthy end of the resistor R (Fig. 11). The output voltage V_o will be given by:

$$V_o = \frac{-AIR}{1 + A\beta}$$

It is well known that the effect on V_o of changes in the amplifier gain and non-linearity in the amplifiers is reduced by a factor $(1 + A\beta)$ so improving the constancy of calibration. Variation of β provides a convenient sensitivity control without changing the resistor R. It should be noted

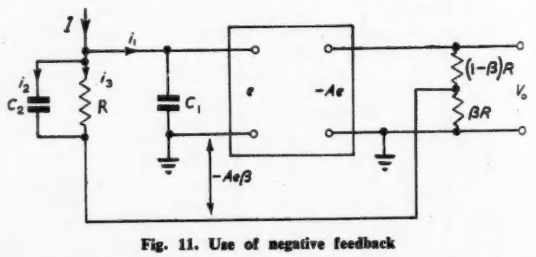


Fig. 11. Use of negative feedback

that the feedback does not reduce the effect of input instability of the electrometer, since this is indistinguishable from the signal.

Without feedback, the input time-constant is given by $R(C_1 + C_2)$ where:

R = input resistor

C_2 = capacitance across it

C_1 = capacitance of input lead to earth.

With feedback, the situation is modified as follows:

$$I = i_1 + i_2 + i_3 \text{ (Fig. 11)}$$
$$= C_1\, de/dt + C_2(1 + A\beta)\, de/dt + (1 + A\beta)\, e/R$$
where $V_o = eA$.
$$= [C_1 + C_2(1 + A\beta)]\, de/dt + (1 + A\beta)\, e/R$$
$$\therefore e = \frac{IR}{1 + A\beta}\left[1 - \exp - \frac{t}{\frac{R[C_1 + C_2(1 + A\beta)]}{1 + A\beta}}\right]$$

The effective time-constant is then

$$\frac{R[C_1 + C_2(1 + A\beta)]}{1 + A\beta} = R\left[\frac{C_1}{1 + A\beta} + C_2\right]$$

As C_1 is usually the larger component, consisting of stray and valve capacitance, a large reduction in time-constant can be made by the feedback.

The capacitance C_2 is formed by the distributed and self-capacitance of the resistor R and usually sets a limit on the lowest obtainable time-constant. It has been shown that the time-constant can be reduced further by the use of guard rings connected to the feedback line[22]. These electrodes reduce the charging currents of the capacitance C_2

and with a suitable arrangement a bandwidth of 150c/s was obtained for $R = 10^{12}\Omega$ and $C_2 = 10pF$.

REFERENCES

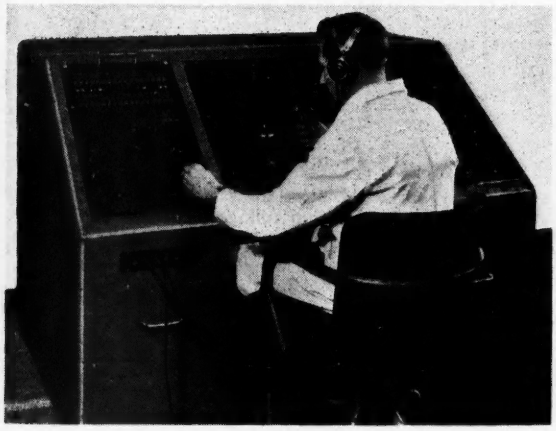
1. TAYLOR, D., SHARPE, J. Nuclear Particle and Radiation Detectors. *Proc. Instn. Elect. Engrs. 98*, Pt. II, 174 (1951).
2. HARRIS, F. K. Electrical Measurements. (Wiley, 1951).
3. JONES, R. V., MCCOMBIE, C. W. Brownian Fluctuations in Galvanometers and Galvanometer Amplifiers. *Phil. Trans. Roy. Soc. A. 244*, 205 (1952).
4. COPELAND, K., DOWNING, A. C., HILL, A. V. A Moving Coil Galvanometer of Extreme Sensitivity. *J. Sci. Instrum. 30*, 40 (1953).
5. KANDIAH, K., BROWN, D. E. High Gain D.C. Amplifiers. *Proc. Instn. Elect. Engrs. 99*, Pt. II, 314 (1952).
6. WILLIAMS, F. C., NOBLE, S. W. The Fundamental Limitations of the Second Harmonic Type of Magnetic Modulator as Applied to the Amplification of Small D.C. Signals. *Proc. Instn. Elect. Engrs. 97*, Pt. II, 445 (1950).
7. MACADAM, W., TARPLEY, R. E., WILLIAMS, A. J. D.C. Amplifier with Reduced Zero Offset. *Electronics 24*, 128 (August, 1951).
8. KROEBEL, W., A. Highly Sensistive D.C. Amplifier with High Input Resistance. *Z. P'y. Bd.* 133, S30-40 (1952).
9. O'MEARA, F. E. Circuits for Ultra Sensitive Electrometers. *Rev. Sci. Instrum. 22*, 106 (1951).
10. NEHER, H. V. Physical Laboratory Practice. Ed. Strong, J. Ch. VI (Blackie, 1946).
11. HANSEN, W. W. On the General Theory of Electrometer Design. *Rev. Sci. Instrum. 7*, 182 (1936).
12. MILATZ, J. M. W., VAN ZOLINGEN, J. J., VON IPEREN, B. B. The Reduction of Brownian Movement in Electrometers. *Physica. 19*, 195 (1953).
13. METCALF, G. F., THOMPSON, B. J. A Low Grid Current Valve. *Phys. Rev. 36*, 1489 (1930).
14. NIELSEN, C. E. Measurement of Small Currents : Characteristics of Types 38, 954 and 959, as Reduced Grid Current Tubes. *Rev. Sci. Instrum. 18*, 18 (1947).
15. HAY, G. A. Receiving Valves Suitable for Electrometer Use. *Electronic Engng. 23*, 258 (1951).
16. HARRIS, E. J. An Electrometer Impedance Converter. *Electronic Engng. 23*, 109 (1951)
17. HUGHES, H. A. Electrometer Valve Balanced Circuit. *Electronic Engng. 23*, 217 (1951).
18. DUBRIDGE, L. A. Amplification of Small Direct Currents. *Phys. Rev. 37*, 392 (1931).
19. LITTLE, G. C. A New Double Electrometer Valve. *Electronic Engng. 19*, 365 (1947).
20. LAFFERTY, J. M., KINGDON, K. H. Improvements in the Stability of the FP-54 Electrometer Tube. *J. Appl. Phys. 17*, 894 (1946).
21. HAFSTAD, L. R. Application of the FP-54 Pliotron to Atomic Disintegration Studies. *Phys. Rev. 44*, 201 (1933).
22. HARRIS, E. J., BISHOP, P. O. The Design and Limitations of D.C. Amplifiers. *Electronic Engng. 21*, 332 (1949).
23. WIJNGAARDEN, J. G., VAN, HAAN, E. F. Low Frequency Noise in Electron Tubes. *Physica. 18*, 705 (1952).
24. PEIRSON, D. H. A D.C. Amplifier Using an Electrometer Valve. *Electronic Engng. 22*, 48 (1950).
25. KESSLER, G. The D.C. Voltage Amplifier. *Arch. tech. Messen.* Issue 198 (Ref. Z634-8) 163 (July, 1952).
26. CHANCE, B., LEGALLAIS, V. Rapid and Sensitive Spectrophotometry. *Rev. Sci. Instrum. 22*, 627 (1951).
27. British Patent Specification 667255.
28. CHANCE, B. Waveforms. M.I.T. Radiation Series (*19*, 414 (McGraw-Hill, 1949).
29. THOMAS, D. G. A., FINCH, H. W. A Simple Vibrating Condenser Electrometer. *Electronic Engng. 22*, 395 (1950).
30. Electronic Equipment. *Electronic Engng. 23*, 193 (1951).
31. Electronic Equipment. *Electronic Engng. 24*, 340 and 471 (1952).
32. TAIEB, J. Reduction of Measuring Time of Low Current Amplifiers Without Loss of Sensitivity. *C.R. Avad. Sci. (Paris) 233*, 50 (1950), also *Transactions of Instruments and Measurements Conference*, (Stocknolm 52). 19.

FLIGHT SIMULATORS FOR CANADA

THE Royal Canadian Air Force has recently taken delivery of the first of ten flight simulators being built for them by Messrs. Redifon Ltd, London.

The type F86E simulator consists basically, of a replica of the Sabre cockpit with every instrument and control exactly reproduced, with control panels and recorders for the instructor together with the associated computing equipment.

Practically any navigational problem or emergency condition can be presented to the trainee pilot. These problems and the normal conditions of flight are translated by an analogue com-



The instructor's console.

putor consisting of a system of electronic and electro-mechanical apparatus into instrument readings and control responses.

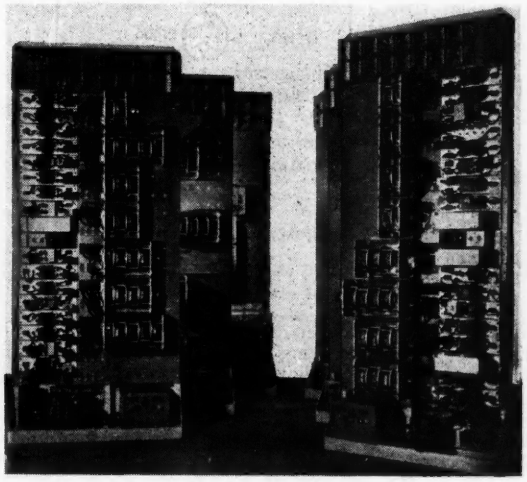
The pilot's handling of the controls and equipment produces the same results in the flight simulator as would be experienced in an actual aircraft—without any of the hazard and at a fraction of the cost of actual flight.

It is thus possible to feed emergency conditions into the simulator—conditions, which, with a student pilot, might in the air, easily lead to disaster. Such things as engine or instrument failures can be introduced and repeated at will until the instructor is satisfied that the trainee's actions are immediate and correct.

Appropriate aural effects and correct feel of all controls are examples of the faithfulness of simulation. In fact, the only impressions which are not given are the physical effect of accelerations and the external view through the canopy.

When the flight simulator is in operation, signals originating from the controls are fed through valve amplifiers to actuate a number of interconnected electro-mechanical servo units which form the analogue computors.

The servo units are reversible motor-driven integrators or position controlled devices carrying assemblies of potentiometers, with windings contoured to produce various voltage functions. The voltages are combined to interrelate the com-



The analogue computors.

puting servos and thereby solve the appropriate equations. Every movement of the elevator, ailerons, flaps, rudder and throttle is translated into the reading of the airspeed, rate of climb, rate of turn, pitch and roll instruments in the cockpit. Throttle adjustment results in appropriate variations in the simulated engine noises which also vary with airspeed. Gunfire and brake squeal are examples of other noises generated.

A large number of failures and effects can be fed in from the instructor's console, including fires in various zones of the aircraft; failure of supplies; flight instrument failures; hydraulic failures; undercarriage faults and errors in all engine and fuel system instruments. The radio aids equipment on the console and the two recorders give full operation—including failures and deficiencies—of the radio facilities. Each aid is independently adjustable for different transmitter locations.

Voltage Stabilizers for Microwave Oscillators

Effects on Stability of Variations in Valve Heater Voltage

By F. A. Benson*, M.Eng., Ph.D., A.M.I.E.E., M.I.R.E., and G. V. G. Lusher*, B.Eng., Grad.I.E.E.

A mathematical analysis is given of the effect of the varying heater voltage on the stability of the types of valve stabilizer commonly used for the operation of low-power microwave oscillators. It is shown that, although analyses assuming constant heater voltage are not perfectly adequate, the effects of heater voltage on the stability of series-parallel arrangements are not as serious as might be expected.

THE characteristics required of voltage supplies for satisfactory operation of low-power microwave oscillators are now well known. A number of suitable power supply circuits have been given previously by one of the authors[1,2] and have been examined, in detail mathematically. In calculating the performances of these stabilizers it was assumed that the heater voltages of the valves remained constant, but that this is not entirely adequate has been pointed out[3]. Additional calculations

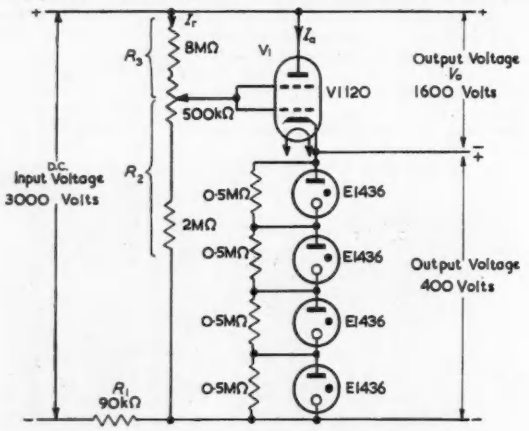


Fig. 1. Parallel valve stabilizer for microwave oscillator

have, therefore, now been carried out on each circuit to find the effects of heater-voltage variations on the stability. The results are presented below.

To make the calculations it was found necessary to investigate the variations of triode characteristics with heater voltage and the results of these examinations have already been given[4]. It has been shown that the anode voltage V_a, the grid voltage V_g and the anode current I_a of a triode are related by the expression:

$$V_a = r_a I_a - \mu V_g - cr_a \quad \ldots\ldots\ldots\ldots \quad (1)$$

where μ is the amplification factor of the valve,

r_a is the anode resistance of the valve,

and c is a constant which for many triodes is normally nearly zero.

When the heater voltage of the valve varies it would be expected that μ, r_a and c will all change. Such changes must be determined experimentally. Measurements on a number of triodes which are commonly used in voltage stabilizer circuits have shown, however, that the quantity c is the only one that need be considered because the values of μ and r_a are reasonably constant even for fairly large heater voltage variations. Thus, in making calculations on a stabilizer where the heater voltages of the valves vary, equation (1) must be used. Then proceeding in the usual way with the calculations an expression is obtained for the output voltage in terms of several known values and certain quantities (c's) which are functions of heater voltages. Consequently the ratio of the percentage change of output voltage to the percentage change of heater voltage can be found providing that it is known how the various c's depend on the heater voltage.

Consider first the parallel-valve stabilizer of Fig. 1. The

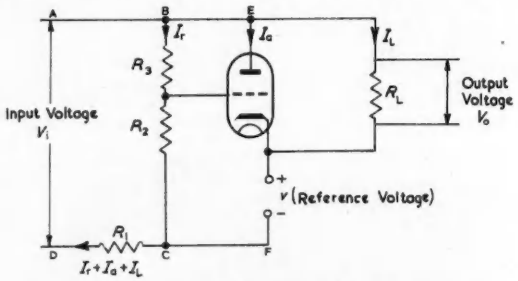


Fig. 2. Equivalent circuit of Fig. 1

circuit may be redrawn for the purpose of analysis as in Fig. 2. Let the currents and voltages be as shown.

By Kirchhoff's laws the following equations are obtained:

From A to B to C to D:

$$V_i = I_r(R_2+R_3)+(I_r+I_a+I_L)R_1 \quad \ldots\ldots\ldots \quad (2)$$

From A to E to F to D:

$$V_i = (I_r + I_a + I_L)R_1 + v + I_L R_L \quad \ldots\ldots\ldots \quad (3)$$

Assuming linear valve characteristics:

$$I_L R_L = I_a r_a - \mu V_g - cr_a \quad \ldots\ldots\ldots \quad (4)$$

In this case:

$$V_g = I_r R_2 - v \quad \ldots\ldots\ldots\ldots\ldots \quad (5)$$

From (4) and (5):

$$I_L R_L = I_a r_a - \mu(I_r R_2 - v) - cr_a \quad \ldots\ldots\ldots \quad (6)$$

From (2), (3) and (6) re-arranging the terms:

$$I_a R_1 + I_r(R_1 + R_2 + R_3) + I_L R_1 = V_i \quad \ldots\ldots \quad (7)$$

$$I_a R_1 + I_r R_1 + I_L(R_1 + R_L) = V_i - v \quad \ldots\ldots \quad (8)$$

$$I_a r_a - I_r \mu R_2 - I_L R_L = -\mu v + cr_a \quad \ldots\ldots \quad (9)$$

Subtracting (8) from (7):

$$I_r = (v + I_L R_L)/(R_2 + R_3) \quad \ldots\ldots\ldots \quad (10)$$

From (8) and (10):

$$I_a = [V_i - v - R_1(v + I_L R_L)/(R_2 + R_3) - I_L(R_1 + R_L)]/R_1 \quad \ldots \quad (11)$$

* *The University of Sheffield.*

From (9):

$$I_a=[-\mu v+cr_a+I_LR_L+\mu R_2(v+I_LR_L)/(R_2+R_3)]/r_a \quad .. \quad (12)$$

From (11) and (12) and remembering that $I_LR_L = V_o$:

$$V_o = \frac{V_ir_a(R_2+R_3)+v\left\{\mu R_1R_3-r_a(R_1+R_2+R_3)\right\}-cr_a(R_2+R_3)R_1}{R_1r_a(R_2+R_3)/R_L+[R_1(R_2+R_3+\mu R_2)+r_a(R_1+R_2+R_3)]} \quad ..... \quad (13)$$

$$dV_o/dV_h = \frac{-dc/dV_h\ r_a(R_2+R_3)R_1}{R_1r_a(R_2+R_3)/R_L+[R_1(R_2+R_3+\mu R_2)+r_a(R_1+R_2+R_3)]} \quad ..... \quad (14)$$

Hence the ratio of the percentage change of output voltage to the percentage change of heater voltage $dV_o/V_o \cdot V_h/dV_h =$

$$\frac{-dc/dV_h\ r_a(R_2+R_3)R_1 \cdot V_h}{V_ir_a(R_2+R_3)+v\left\{\mu R_1R_3-r_a(R_1+R_2+R_3)\right\}-cr_a(R_2+R_3)} \quad ..... \quad (15)$$

For the particular case under consideration:

$R_1 = 90\text{k}\Omega$ $R_3 = 8{\cdot}4\text{M}\Omega$ $V_i = 3\,000\text{V}$ $\mu = 300$

$R_2 = 2{\cdot}1\text{M}\Omega$ $r_a = 100\text{k}\Omega$ $v = 400\text{V}$

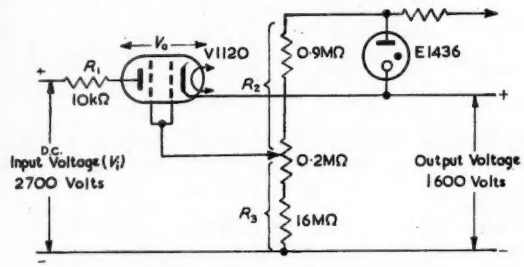


Fig. 3. Series valve stabilizer for microwave oscillator

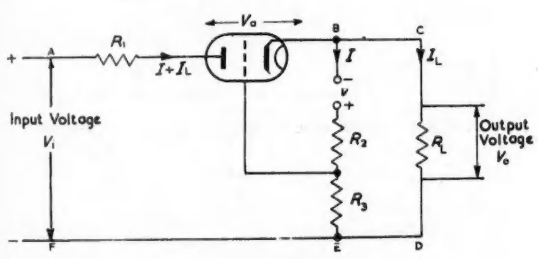


Fig. 4. Equivalent circuit of Fig. 3

Assume $c = 0$. c changed by 0·8mA for a change of V_h of 10 per cent.

Hence $dV_o/V_o \cdot V_h/dV_h = -0{\cdot}008$

i.e. a change of heater voltage of 10 per cent causes the output voltage to change by 0·08 per cent, i.e. by about 1·3 volts.

It should be noted that previous calculations, made assuming constant valve-heater voltage, showed that a change of input voltage of 10 per cent caused the output voltage to change by about 5 volts. Further, a change in load resistance of 10 per cent causes the output voltage to change by about 1 volt only.

Consider now the series-valve circuit of Fig. 3 which may be redrawn for the purpose of analysis as in Fig. 4. Let the currents and voltages be as shown.

By Kirchhoff's laws the following equations are obtained:

From A to B to C to D to F:

$$V_i = R_1(I_L + I) + V_a + I_LR_L \quad ..... \quad (16)$$

From B to E to D to C:

$$v = I(R_2 + R_3) - I_LR_L \quad ..... \quad (17)$$

With linear valve characteristics as in the previous case:

$$V_a = (I_L + I)r_a - \mu V_g - cr_a \quad ..... \quad (18)$$

and

$$V_g = v - IR_2 \quad ..... \quad (19)$$

Therefore, proceeding as in the previous case and remembering that $I_LR_L = V_o$, it is found that:

$$V_o = \frac{R_L[(V_i+cr_a)(R_2+R_3)+v(\mu R_3-R_1-r_a)]}{R_L(R_1+r_a+\mu R_2+R_2+R_3)+(R_1+r_a)(R_2+R_3)} \quad . \quad (20)$$

$$dV_o/dV_h = \frac{R_Lr_a(R_2+R_3)\ dc/dV_h}{R_L(R_1+r_a+\mu R_2+R_2+R_3)+(R_1+r_a)(R_2+R_3)} \quad . \quad (21)$$

Hence, the ratio of the percentage change of output voltage to the percentage change of heater voltage, i.e.

$$\frac{dV_o}{V_o}\ \frac{V_h}{dV_h} = \frac{dc/dV_h \cdot r_a(R_2+R_3) \cdot V_h}{(V_i+cr_a)(R_2+R_3)+v(\mu R_3-R_1-r_a)} \quad (22)$$

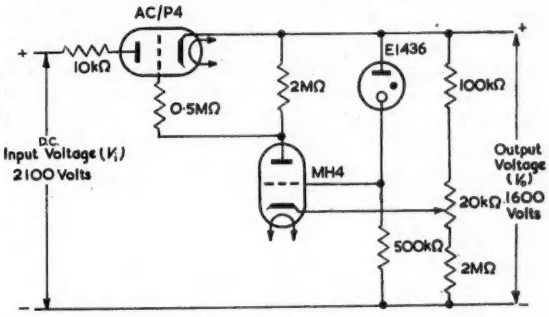


Fig. 5. Series parallel valve stabilizer for microwave oscillator

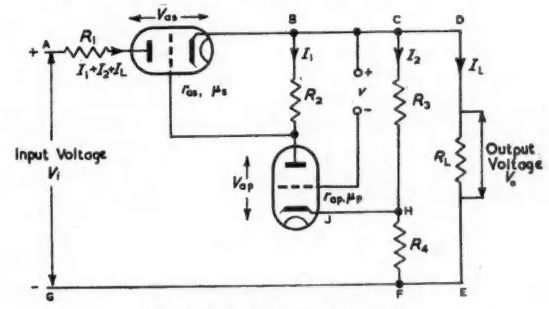


Fig. 6. Equivalent circuit of Fig. 5

For the particular case under consideration:

$R_1 = 10\text{k}\Omega$ $R_3 = 16\text{M}\Omega$ $V_i = 2\,700\text{V}$

$R_2 = 1\text{M}\Omega$ $r_a = 100\text{k}\Omega$ $v = 100\text{V}$ $\mu = 300$

Assume $c = 0$. c changed by 0·8mA for a change of V_h of 10 per cent.

$$\therefore \quad \frac{dV_o}{V_o}\ \frac{V_h}{dV_h} = +0{\cdot}026$$

i.e. a change of heater voltage of 10 per cent causes the output voltage to change by 0·26 per cent, i.e. by about 4·2 volts.

It should be noted that previous calculations, made assuming constant valve heater voltage, showed that a change of input voltage of 10 per cent caused the output voltage to change by about 14 volts. Further, a change in load resistance of 10 per cent causes the output voltage to change by 3·5 volts.

The first arrangement of three series-parallel valve stabilizer circuits will now be considered. It is shown in Fig. 5. The circuit may be redrawn for the purpose of analysis as in Fig. 6. Let the currents and voltages be as shown.

By Kirchhoff's laws the following equations are obtained:

From A to B to D to E to G:

$$V_i = (I_1 + I_2 + I_L)R_1 + V_{as} + I_L R_L \quad \ldots\ldots (23)$$

From B to C to H to J:

$$V_{ap} = I_2 R_3 - I_1 R_2 \quad \ldots\ldots\ldots\ldots (24)$$

From C to D to E to F:

$$I_L R_L = I_2 R_3 + (I_1 + I_2) R_4 \quad \ldots\ldots\ldots (25)$$

With linear valve characteristics:

$$V_{as} = (I_1 + I_2 + I_L) r_{as} - \mu_s V_{gs} - c_s r_{as} \quad \ldots. (26)$$

and

$$V_{gs} = I_1 R_2 \quad \ldots\ldots\ldots\ldots (27)$$

where r_{as}, μ_s and c_s refer to the series valve.

Also

$$V_{ap} = I_1 r_{ap} - \mu_p V_{gp} - c_p r_{ap} \quad \ldots\ldots\ldots (28)$$

and

$$V_{gp} = I_2 R_3 - v \quad \ldots\ldots\ldots\ldots (29)$$

where r_{ap}, μ_p and c_p are the constants of the parallel valve.

Therefore, proceeding as before and remembering that $V_o = R_L I_L$ it is found that:

$$V_o = \frac{R_L[aV_i + bv + c_p r_{ap} R_4 (R_1 + r_{as}) - (R_1 + r_{as} + \mu_s R_2)(R_3 + R_4)\, c_p r_{ap} + c_s r_{as} a]}{c} \quad \ldots\ldots\ldots (30)$$

where

$$a = (R_3 + R_4)(R_2 + r_{ap}) + R_3 R_4 (1 + \mu_p) \quad \ldots\ldots\ldots\ldots (31)$$

$$b = \mu_p [R_3 (R_1 + r_{as} + \mu_s R_2) + R_4 \mu_s R_2] \quad \ldots\ldots\ldots (32)$$

$$c = a(R_1 + R_L + r_{as}) + R_L (R_1 + r_{as})(R_2 + r_{ap}) + R_3 R_L (R_1 + r_{as} + \mu_s R_2)(1 + \mu_p) \quad \ldots. (33)$$

$$\therefore \frac{dV_o}{dV_h} = -\frac{R_L}{c} \left[\frac{dc_p}{dV_h} r_{ap} \left\{ (R_4 \mu_s R_2 + R_3 (R_1 + r_{as} + \mu_s R_2) \right\} - \frac{dc_s}{dV_h} r_{as} a \right] \quad (34)$$

Hence the ratio of the percentage change of output voltage to the percentage change of heater voltage, i.e.

$$\frac{dV_o}{V_o} \cdot \frac{V_h}{dV_h} = - \frac{[dc_p/dV_h\, r_{ap} \{ R_4 \mu_s R_2 + R_3 (R_1 + r_{as} + \mu_s R_2) \} - dc_s/dV_h\, r_{as} a] V_h}{[aV_i + bv + c_p r_{ap} R_4 (R_1 + r_{as}) - (R_1 + r_{as} + \mu_s R_2)(R_3 + R_4)\, c_p r_{ap} + c_s r_{as} a]} \quad \ldots\ldots\ldots\ldots (35)$$

For the particular case under consideration:

$R_1 = 10\text{k}\Omega$ $\quad R_3 = 110\text{k}\Omega$ $\quad V_i = 2\,100\text{V}$ $\quad r_{as} = 2{\cdot}8\text{k}\Omega$

$R_2 = 2\text{M}\Omega$ $\quad R_4 = 2\text{M}\Omega$ $\quad v = 100\text{V}$ $\quad r_{ap} = 100k\Omega$

$\mu_s = 18$ $\quad \mu_p = 25$ $\quad c_p = c_s = 0$

c_p changed by 0·7mA for a 10 per cent change of V_h and c_s changed by 1·1mA for a 10 per cent change of V_h.

Therefore $\dfrac{dV_o}{V_o} \cdot \dfrac{V_h}{dV_h} = -0{\cdot}063$

i.e. changes of heater voltages of 10 per cent cause the output voltage to change by 0·63 per cent, i.e. by about 10 volts.

It should be noted that previous calculations, made assuming constant valve heater voltage, showed that a change in input voltage of 10 per cent caused the output voltage to change by about 16 volts. A change in load resistance of 10 per cent causes the output voltage to change by about 1 volt.

The second series-parallel valve circuit to be considered is shown in Fig. 7 and for the purpose of analysis it may be redrawn as in Fig. 8. Let the currents and voltages be as shown.

By Kirchhoff's laws the following equations are obtained:

From A to B to C to D to E to H:

$$V_i = R_1 (I_1 + I_2 + I_L) + V_{as} + I_L R_L \quad \ldots. (36)$$

From A to B to G to H:

$$V_i = R_1 (I_1 + I_2 + I_L) + I_1 R_2 + V_{ap} \quad \ldots. (37)$$

From C to D to E to F:

$$v = I_2 (R_3 + R_4) - I_L R_L \quad \ldots\ldots\ldots (38)$$

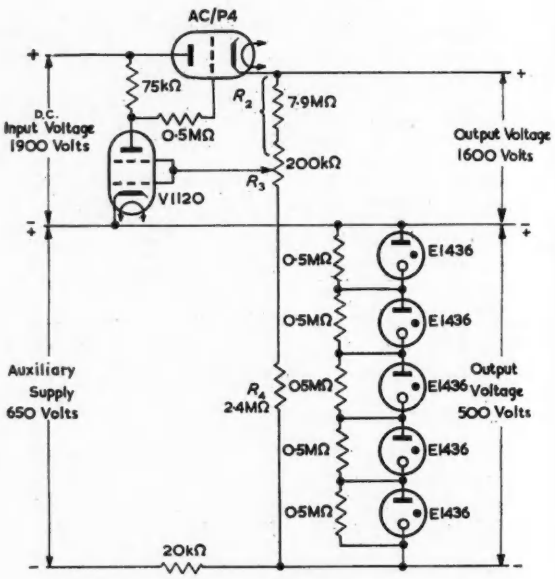


Fig. 7. Series parallel valve stabilizer for microwave oscillator

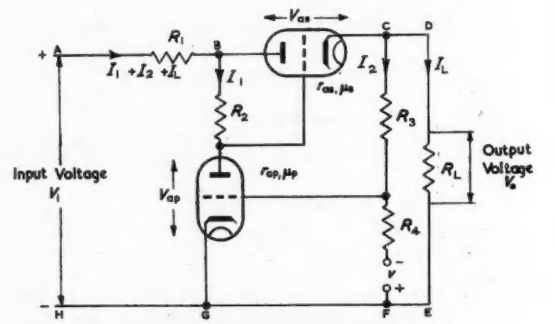


Fig. 8. Equivalent circuit of Fig. 7

With linear valve characteristics:

$$V_{as} = (I_2 + I_L) r_{as} - \mu_s V_{gs} - r_{as} C_s \quad \ldots\ldots (39)$$

where

$$V_{gs} = V_{ap} - I_L R_L \quad \ldots\ldots\ldots\ldots (40)$$

also

$$V_{ap} = I_1 r_{ap} - \mu_p V_p - r_{ap} C_p \quad \ldots\ldots\ldots\ldots (41)$$

and

$$V_{gp} = I_2R_4 - v \quad \ldots\ldots\ldots\ldots \quad (42)$$

where r_{as}, r_{ap}, μ_s, μ_p, c_s and c_p have the same meanings as before.

Therefore, proceeding as before and remembering that $V_o = I_LR_L$ it is found that:

$$V_o = \frac{R_L[\alpha V_1 + \beta v + \delta]}{\gamma} \quad \ldots\ldots\ldots\ldots \quad (43)$$

where

$$\alpha = (R_3 + R_4)\left\{R_2 + r_{ap}(1 + \mu_s)\right\} \quad \ldots\ldots\ldots\ldots\ldots \quad (44)$$

$$\beta = (R_1 + R_2)(\mu_s\mu_pR_3 - r_{as}) - R_1 \left\{R_2 + r_{ap}(1 + \mu_s) - R_3\mu_p\right\} - r_{ap}r_{as} \quad \ldots\ldots\ldots\ldots \quad (45)$$

$$\gamma = (R_3 + R_4)[R_1(\mu_sr_{ap} + r_{as}) + (R_1 + r_{as})(R_2 + r_{ap})] + R_L[R_1(r_{as} + \mu_sr_{ap}) + r_{ap}(R_1 + r_{as}) + \mu_pR_4(R_1\mu_s + R_1) + R_2(R_1 + r_{as} + \mu_s\mu_pR_4) + (1 + \mu_s)(R_3 + R_4)(R_1 + R_2 + r_{ap})] \quad \ldots\ldots\ldots\ldots \quad (46)$$

$$\delta = (R_3 + R_4)[r_{as}c_s'R_1 + R_2 + r_{ap}) - r_{ap}c_p(R_1 + \mu_sR_1 + \mu_sR_2)] \quad \ldots\ldots\ldots\ldots \quad (47)$$

Therefore:

$$dV_o/dV_h = R_L[(R_3 + R_4)\left\{r_{as}\, dc_s/dV_h\,(R_1 + R_2 + r_{ap}) - r_{ap}\, dc_p/dV_h(R_1 + \mu_sR_1 + \mu_sR_2)\right\}] / \gamma \quad \ldots\ldots\ldots\ldots \quad (48)$$

Hence, the ratio of the percentage change of output voltage to the percentage change of heater voltage,

$$\frac{dV_o}{V_o} \cdot \frac{V_h}{dV_h} = \frac{[(R_3 + R_1)\left\{r_{as}\ dc_s/dV_h\ (R_1 + R_2 + r_{ap}) - r_{ap}\ dc_p/dV_h\ (R_1 + \mu_sR_1 + \mu_sR_2)\right\}]\ V_h}{[(R_3 + R_4)\left\{R_2 + r_{ap}(1 + \mu_s)\right\}V_1 + [(R_1 + R_2)(\mu_s\mu_pR_3 - r_{as}) - R_1\left\{R_2 + r_{ap}(1 + \mu_s) - R_3\mu_p\right\} - r_{ap}r_{as}]v + (R_3 + R_4)\left\{r_{as}c_s(R_1 + R_2 + r_{ap}) - r_{ap}c_p(R_1 + \mu_sR_1 + \mu_sR_2)\right\}]} \quad \ldots\ldots\ldots\ldots \quad (49)$$

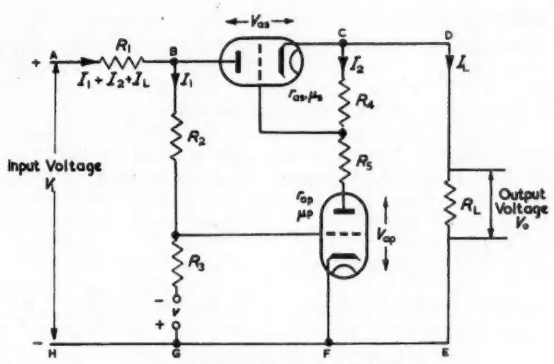


Fig. 10. Equivalent circuit of Fig. 9

For this particular case:

$R_1 = 0$	$R_4 = 2{\cdot}5\text{M}\Omega$	$r_{ap} = 100\text{k}\Omega$	$V_i = 1\,900\text{V}$
$R_2 = 75\text{k}\Omega$	$R_L = 260\text{k}\Omega$	$\mu_s = 18$	$v = 500\text{V}$
$R_3 = 8\text{M}\Omega$	$r_{as} = 2{\cdot}8\text{k}\Omega$	$\mu_p = 300$	$c_p = c_s = 0$

c_p and c_s changed by 0·8mA and 1·1mA respectively for a change in heater voltage of 10 per cent.

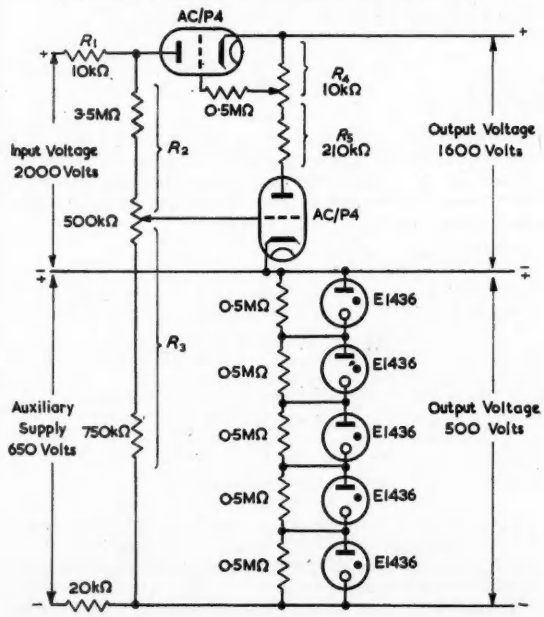
Hence

$$\frac{dV_o}{V_o} \cdot \frac{V_h}{dV_h} = -0{\cdot}007$$

i.e. a change of heater voltage of 10 per cent causes the output voltage to change by 0·07 per cent, i.e. by about 1·1 volts.

It should be noted that previous calculations, made assuming constant valve-heater voltage, showed that a change of input voltage of 10 per cent caused the output voltage to change by about 4 volts. Further, a change in load resistance of 10 per cent causes the output voltage to change by 0·003 volt only.

Fig. 9. Series parallel valve stabilizer for microwave oscillator



The third series-parallel circuit is shown in Fig. 9 and may be redrawn as in Fig. 10. Let the currents and voltages be as shown.

By Kirchhoff's laws the following equations are obtained:

From A to B to G to H:

$$V_i = R_1(I_1 + I_2 + I_L) + (R_2 + R_3)I_1 - v \quad \ldots\ldots \quad (50)$$

From A to D to E to H:

$$V_i = R_1(I_1 + I_2 + I_L) + V_{as} + I_LR_L \quad \ldots\ldots \quad (51)$$

From C to D to E to F:

$$V_{ap} = I_LR_L - (R_4 + R_5)I_2 \quad \ldots\ldots\ldots \quad (52)$$

With linear valve characteristics:

$$V_{as} = (I_L + I_2)r_{as} - \mu_s(-R_4I_2) - c_sr_{as} \quad \ldots\ldots \quad (53)$$

and

$$V_{ap} = I_2r_{ap} - \mu_p(I_1R_3 - v) - c_pr_{ap} \quad \ldots\ldots\ldots \quad (54)$$

where r_{as}, r_{ap}, μ_s, μ_p, c_s and c_p have the same meanings as before.

Therefore, proceeding as before and remembering that $V_o = I_LR_L$ it is found that:

$$V_o = R_L/C[Av - BV_1 - c_pr_{ap}\left\{\Sigma R(R_1 + r_{as} + \mu_sR_4) - R_1^2\right\} + R_3\mu_pR_1r_{as}c_s + c_sr_{as}\,\Sigma R(R_4 + R_5 + r_{ap})] \quad \ldots\ldots\ldots \quad (55)$$

where

$$A = \mu_p\left\{\Sigma R(R_1 + r_{as} + \mu_s R_4) - R_1^2\right\} - R_3\mu_p(R_1 + r_{as} + \mu_s R_4) - R_1(R_4 + R_5 + r_{ap}) \quad \ldots\ldots (56)$$

$$B = R_3\mu_p(r_{as} + \mu_s R_4) - (R_2 + R_3)(R_4 + R_5 + r_{ap}) \quad \ldots\ldots (57)$$

$$C = R_3\mu_p R_1(R_L - \mu_s R_4) - (R_4 + R_5 + r_{ap})\left\{R_1^2 - \Sigma R(R_1 + R_L + r_{as})\right\} + R_L\Sigma R(R_1 + r_{as} + \mu_s R_4) - R_L R_1^2 \quad \ldots (58)$$

$$\Sigma R = R_1 + R_2 + R_3 \quad \ldots\ldots (59)$$

therefore:

$$\frac{dV_o}{dV_h} = \frac{R_L}{c}\left[-dc_p/dV_h \cdot r_{ap}\left\{\Sigma R(R_1 + r_{as} + \mu_s R_1) - R_1^2\right\} + dc_s/dV_h\left\{R_3\mu_p R_1 r_{as} + r_{as}\Sigma R(R_4 + R_5 + r_{ap})\right\}\right] \quad \ldots\ldots (60)$$

$$\therefore \frac{dV_o}{dV_h}\cdot\frac{V_h}{V_o} = \frac{\left[-dc_p/dV_h \cdot r_{ap}\left\{\Sigma R(R_1 + r_{as} + \mu_s R_1) - R_1^2\right\} + dc_s/dV_h\left\{R_3\mu_p R_1 r_{as} + r_{as}\Sigma R(R_4 + R_5 + r_{ap})\right\}\right]V_h}{\left[Av - BV_i - c_p r_{ap}\left\{\Sigma R(R_1 + r_{as} + \mu_s R_4) - R_1^2\right\} + R_3\mu_p R_1 r_{as} c_s + c_s r_{as}\Sigma R(R_4 + R_5 + r_{ap})\right]} \quad \ldots\ldots (61)$$

In this case:

$R_1 = 10\text{k}\Omega$	$R_4 = 2{\cdot}5\text{k}\Omega$	$\mu_s = \mu_p = 20$
$R_2 = 3{\cdot}75\text{M}\Omega$	$R_5 = 217{\cdot}5\text{k}\Omega$	$v = 500\text{V}$
$R_3 = 1\text{M}\Omega$	$r_{as} = r_{ap} = 2{\cdot}8\text{k}\Omega$	$c_s = c_p = 0$

c_s and c_p change by 1·1mA for a change of heater voltage of 10 per cent.

Therefore: $\dfrac{dV_o}{V_o}\ \dfrac{V_h}{dV_h} = -0{\cdot}0011$

i.e. a 10 per cent change of heater voltage produces a change of only 0·011 per cent in the output voltage, i.e. about 0·18 volt.

It should be noted that the output voltage is independent of the input voltage changes, but a 10 per cent change in load resistance causes the output voltage to change by about 1·6 volt.

Conclusions

The results of the calculations confirm that analyses of thermionic-valve circuits which assume that the heater voltages of the valves remain constant are not perfectly adequate, because very frequently the heaters are supplied from windings of transformers fed directly by the mains. The effects of heater voltage variations on the stability of series-parallel arrangements are not as serious as might at first sight be expected. This is so because the two valves produce changes in output voltage of opposite sign.

In the case of a single series-valve stabilizer, however, the effects of heater voltage variations are rather serious. It is interesting to note that for some circuits the stability obtained when both input voltage and heater voltages vary simultaneously, is better than when the input voltage alone changes.

REFERENCES

1. Benson, F. A. Voltage Stabilizers. (Electronic Engineering Monograph. 1950).
2. Benson, F. A. Voltage Stabilizers. *Electronic Engng. 21*, 155, 200, 243 and 300 (1949).
3. Use of the 85A1 Stabilizer in Stabilized D.C. Power Supplies. *Mullard Technical Report No.* 13/1949 (February, 1949).
4. Benson, F. A., Lusher, G. V. G., Seaman, M. S. Variations of Triode Characteristics with Heater Voltage. *Electrical J. 151*, 481 (1953).

An Electrical Backlash Circuit

and its use in a dividing chain

By C. H. Banthorpe*

IF two valves are coupled as in Fig. 1, the circuit has the property that only one of the valves will take current and the current may be switched rapidly from one to the other by changing the voltages on g_1 of V_1. However, there is considerable backlash in the circuit, i.e. the grid voltage required to change from one stable state to the other is quite different to the voltage to change back. This effect was noticed by the author some years ago as an undesirable feature of a circuit, and was later investigated. It has also been investigated, and exploited, by the Radio Corporation of America[1].

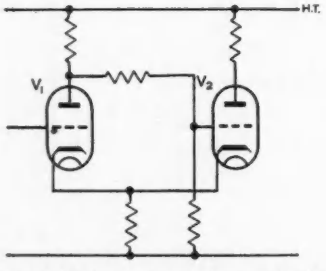


Fig. 1. Basic "switching" circuit having considerable backlash

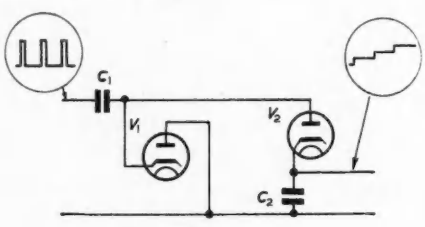


Fig. 2. Divider circuit

One way in which this circuit can be profitably employed is as a discharger in a divider chain. Thyratrons, or blocking oscillators have been used, but this type of circuit is probably more reliable.

The divider circuit is well known, and is shown in Fig. 2.

* *Derwent Radio (Central Equipment Ltd.).*

Briefly, positive pulses are applied to the input, each pulse putting a charge into C_1 and C_2 as diode V_2 conducts. As the capacitance of C_2 is much larger than C_1 most of the pulse voltage appears across C_1. At the end of the pulse V_2 becomes open circuit and V_1 conducts and discharges C_1 or D.C. restores it to H.T. negative. C_2 is thus left with a charge until the next pulse, when a second charge is added to the first and so on. The voltage across C_2 therefore rises in steps like a staircase. If C_2 is discharged when the voltage across it rises to a predetermined value then the waveform across it will be a succession of staircase voltages, the number of steps being pre-set.

If the circuit of Fig. 1 is connected across C_2 of Fig. 2 as in Fig. 3 the step voltage will rise until the change-over voltage is reached when current will be transferred from V_4 of Fig. 3 to V_3. At the same time V_3 cathode voltage will fall and as the grid is still considerably positive, V_3 will draw grid current until C_2 is discharged to a point at which the anode current of V_3 is slightly reduced.

The anode voltage of V_3 will then rise slightly, g_1 of V_4 will rise causing anode current to start in V_4, its cathode voltage to rise and with it the cathode of V_3. This will bias off V_3 still more, its anode current will reduce and its anode voltage rise. The action is cumulative and the condition of no current in V_3 and current in V_4 will be re-established.

This state will continue until C_2 is once more charged up to the point where anode current starts in V_3, and the cycle starts again.

As C_2 charges, the effective amplitude of the input pulse is reduced, and this means that the amplitude of each step is less than the preceding one, succeeding amplitudes following an exponential law.

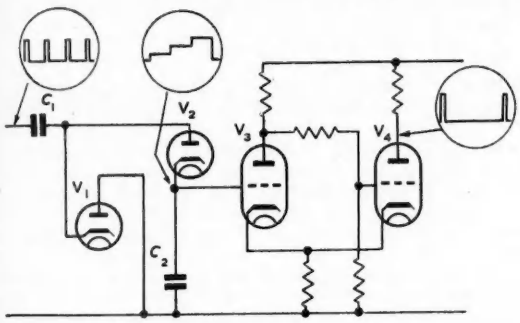


Fig. 3. Use of circuit shown in Fig. 1. as a discharger in a dividing chain

There are several ways in which this undesirable effect can be reduced, but a convenient one is to use a cathode-follower so that the diode V_1 does not D.C. restore C_1 to H.T. negative, but to a step voltage which follows the voltage across C_2. This is done by returning the anode of V_2 to the cathode of a cathode-follower whose grid is connected to C_2, (Fig. 4). In this way the steps can be maintained extremely uniform in amplitude up to 10 with practical values of pulse amplitude, and step heights sufficiently large so that there is no possibility of the divider stage making a wrong count. The cathode-follower is also a convenient point from which the step voltage waveform may be extracted for other purposes.

For low divide ratios it is quite unnecessary to use a cathode-follower so far as accurate dividing is concerned.

It will be seen that a positive pulse will appear at the anode of V_4 during the short time that C_2 is being discharged and this pulse, which occurs once every N input pulses, N being the divide ratio, can be used to operate another divider. The circuit may thus be cascaded for high counts. A circuit used to count down from 20 250c/s to 50c/s ($N = 405$) for a television pattern generator is shown in Fig. 5. As extreme reliability was required the count down was restricted to 3 or 5 per stage, and the order of dividing was chosen so that the ÷ 5 stage waveform could be used as a source of modulation to produce horizontal bars of different intensity from black to white, in the final generated test pattern. This circuit has proved to be extremely stable.

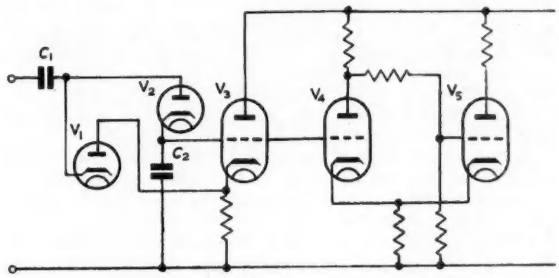


Fig. 4. Method of maintaining voltage steps at a uniform amplitude

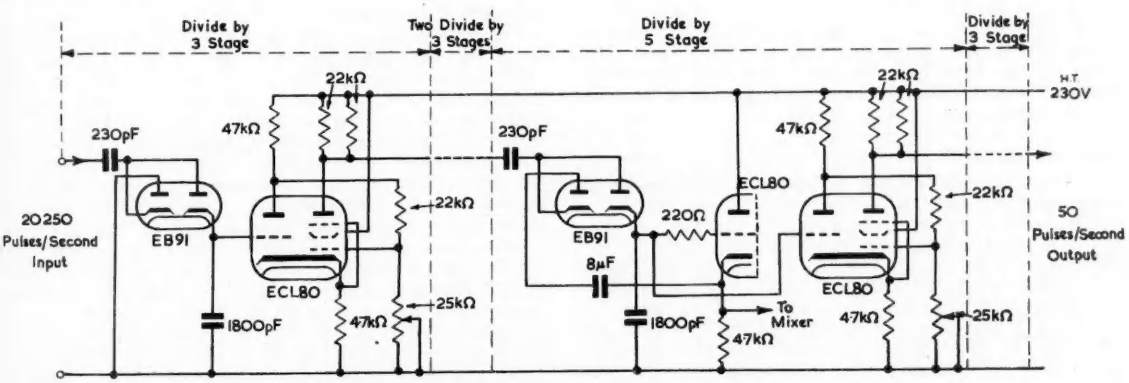


Fig. 5. Circuit for counting down from 20 250c/s to 50c/s for a television pattern generator

All divide by 3 stages are identical

REFERENCE

1. WEBB, R. C., MORGAN, J. M. Simplified Television for Industry. *Electronics 23*, 70 (June, 1950).

A Relay Operated Unit for the Measurement of the Relative Slip Between Two Rollers

By G. J. Parish, B.Sc.*

When two rollers are pressed together, one driving the other, their peripheral speeds will not in general be the same owing to slip at the nip. This article describes a unit which enables the amount of slip to be calculated. The unit records the number of revolutions of each roller between two instants at which the rollers are in the same relative positions; that is, both rollers make an integral number of revolutions in the recording period. From these numbers of revolutions and the roller circumferences the relative peripheral speeds can be calculated. The unit is designed for use with a wide range of roller sizes and speeds.

MANY industrial processes include the passage of material between two rollers, one driving the other. In such a system the rollers will not in general have the same peripheral speed, and the difference in speed can have an important effect on the conditions in the nip; its measurement is, therefore, of some importance.

A convenient way of measuring the speed of one roller relative to that of the other is to count the numbers of revolutions made by both rollers in the same time interval; the relative peripheral speeds can then be calculated from the roller circumferences. It is desirable that the numbers of revolutions should be integral; that is, that at the ends of the interval the rollers should be in the same relative positions. With a two-roller system this can generally be achieved to sufficient accuracy without requiring an unduly long time interval.

If a large number and variety of roller combinations are to be investigated it is desirable to have a unit which can be easily connected to the machine under examination and which will perform both the revolution counting and the estimation of the starting and stopping points. This article describes such a unit.

Design of the Unit

The unit has been designed for use with machines having rollers of from 18 to 60 inches circumference running at speeds up to 100 yards/minute; it is operated by four sets of contact springs and four cams, two fitted to each roller shaft. The starting and stopping action of the unit is initiated by the simultaneous closing of two of these spring sets (this event will be referred to below as a "coincidence"), the other spring sets operate the revolution counters. By thus separating the estimation of the coincidences and the counting it is possible to make the coincidence cams sufficiently short to give the desired accuracy. To initiate both the starting and stopping actions it is merely necessary to energize a single relay, which holds itself on and then sets in motion the appropriate switching sequence. The closing time of the coincidence spring sets need then be only of the order of the operating time of this relay.

In the normal running condition the unit switches on at coincidences 1, 3, 5 .. .. .. and off at 2, 4, 6 .. .. .. the off periods providing a suitable time for the observer to record the counter readings. If it is desired to count for more than a single coincidence period the unit can be made free-running for any number of periods by closing a manually operated switch; this does not affect the unit's switching on, but prevents its switching off. When the manual switch is reopened the unit switches off at the next coincidence.

As the unit is designed for use with any combination of roller sizes it must not be liable to counting errors due to repeated coincidences on adjacent revolutions, a situation which can occur when the rollers are of closely similar radius and the slip per revolution is less than the coincidence cam width. These repeated coincidences could be eliminated by adjusting the cam size at each condition of roller loading and speed to be investigated, but it is more convenient to set the cams to give a reasonable counting time at the highest speed and thereafter to keep their length unchanged. Since the slip can vary appreciably with speed and roller loading, coincidence groups may then appear at lower speeds. These can be made ineffective by arranging that the unit only operates on the first coincidence of a group and ignores the remainder; it does this by resetting the on-off switching relay only after two revolutions have been made by one roller without an intervening coincidence.

The unit employs eight relays to perform the switching functions, and three counters, two of which record the roller revolutions and the third the coincidences. The counters are of the four-digit type made by the Automatic Telephone Company; the relays, with one exception, are of the 3 000 or 600 types, one of them having two windings. The exception is the start relay, the one which is energized by the closing of the coincidence springs; this is an American type somewhat faster in action than the P.O. types, having an operation time of about 7msec.

With these components the unit has given reliable service within the limits of roller sizes and speeds for which it was designed. The range could be extended to higher speeds or smaller rollers by the use of high-speed relays, providing that sufficient time was allowed in each revolution for the operation of the counters. If the revolution time became too short the counters could then be preceded by suitable scaling circuits[1].

Circuit Operation

The operation of the circuit is briefly as follows: none of the relays is energized until the first coincidence of a group switches on the revolution counters. If there is no coincidence on the following revolution the switching relays are reset after the second revolution and counting continues until the unit switches off at the next coincidence. If, however, there is a coincidence during the second revolution the resetting is blocked until two successive revolutions have taken place without an intervening coincidence.

The circuit diagram is shown in Fig. 1. The operation is as follows: initially none of the relays is energized. The first coincidence of a group energizes relay *ST* and counter 3 through GT_1, and relay *GB* by its right-hand winding. These three are held by ST_1 and ST_2 makes the circuit for *GH* and for *CS*, which in its turn makes the circuit for

* *The British Cotton Industry Research Association.*

CC, which prepares the revolution counter circuits at CC_3, CC_4. At the next closing of the counter springs of roller 1 in addition to the operation of counter 1 relay GT is energized through GH_2, and GT_1 makes the circuit for the left-hand winding of GB before breaking the circuit for ST. The operation of GR by GT_2 is thus blocked by GB_2 and relays GH and CS remain energized through GH_1 even though ST_2 has opened. When counting springs 1 open GT and GB release in turn. If a second coincidence occurs at the next revolution, ST, counter 3 and GB are re-energized, and the subsequent operation of GT again fails to operate GR.

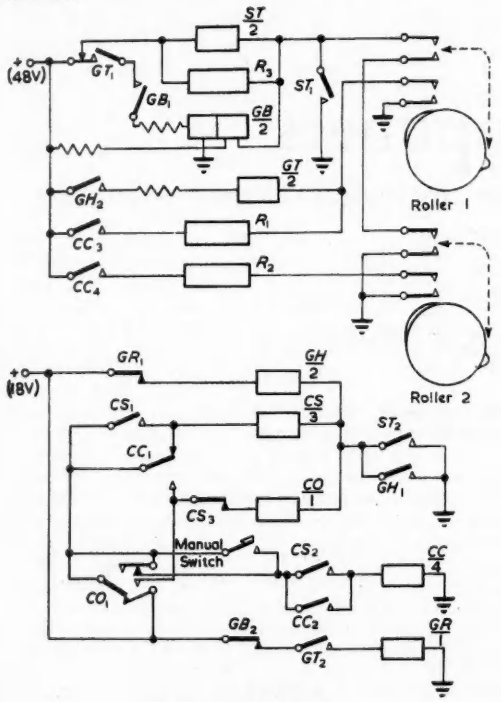


Fig. 1. Circuit diagram

Relays :—

Start	ST	Group Hold	GH
Count Start	CS	Group Test	GT
Count Off	CO	Group Block	GB
Count Control	CC	Group Release	GR

This cycle continues, with counter 3 counting the number of coincidences, until the coincidence group has passed. GT_2 is then free to operate GR, which in turn breaks the circuit for GH and hence for CS. CS_3 prepares the circuit for CO and the unit has been reset.

At the first coincidence of the next group ST_2 makes the circuit for CO through CO_1, CC_1, CS_3. CO's make-before-break holds itself on through CS_3 before breaking the circuit for CC. The revolution counting is stopped by the opening of CC_3, CC_4; coincidence counting continues until the end of the group, when GR operates, and the release of GH breaks the circuit for CO. The unit is then back in its quiescent state.

The closing of the manual control switch does not affect the operation of the unit when switching on, but prevents switching off. Under this condition the operation of CO_1 does not break the circuit for CC, and both CC and CO remain energized until the end of the coincidence group, when the release of CO restores the previous condition. The manual switch may thus be used to extend the counting time over any number of coincidence periods.

The relative positions of the coincidence and the counting cams are not critical; it is only necessary that sufficient time should be allowed between the operation of the corresponding spring sets for the sequences of relay operations to be performed. In addition, the counting cams must be sufficiently long to ensure positive counter action at the highest speed.

Accuracy

Assuming the counting accuracy to be absolute, the accuracy of the unit is dependent solely upon the size of the coincidence cams and the operating time of the start relay. An estimate of the probable error in a single measurement can be made for the condition of single coincidences in the following manner. Suppose the number of revolutions recorded between two coincidences to be M and N for rollers 1 and 2 respectively. The slip of roller 2 relative to roller 1 is computed from these figures assuming them to be exactly integral. This, however, is not necessarily the case; the limiting conditions for the unit to be operated at each coincidence are as shown in Fig. 2, where t_1 and t_2 are the closed times of the springs and τ is the operating time of the start relay. There is thus an uncertainty in the position of roller 2 relative to roller 1 at each coincidence with limits $-(t_2 - \tau)$ and $+ (t_1 - \tau)$, and this uncertainty can be regarded as an error in the determination of N, assuming M to be exactly integral.

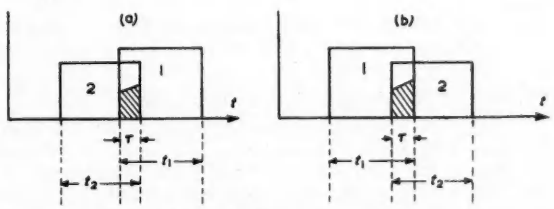


Fig. 2. Limiting conditions for operation of unit

For simplicity let $t_1 = t_2 = t_0$. Then, assuming a rectangular distribution of the uncertainty variables in the intervals $\pm (t_0 - \tau)$ at each coincidence, their difference is a triangularly distributed variable[2] with limits $\pm 2 (t_0 - \tau)$, and hence with a probable error ("semi-interquartile range") given by:

$$\Delta t = \pm (1 - 1/\sqrt{2}) \cdot 2 (t_0 - \tau)$$
$$\approx \pm 0{\cdot}6 (t_0 - \tau)$$

As stated above, in general, the coincidence cams will be set to give a reasonable counting time at the highest speed. This is usually achieved for $t_0 \approx 3\tau$. At the lower speeds τ may thus be neglected, giving $\Delta t = \pm 0{\cdot}6\ t_0$, which can be directly converted into terms of cam length and roller circumference. If ΔN denotes the error in N as a fraction of a revolution, so that the revolutions of roller 2 can be written as $N \pm \Delta N$, then $\Delta N = \Delta t / T_2$ where T_2 is the time for one revolution of this roller. Hence, when τ is negligible.

$$\Delta N = \pm 0{\cdot}6\ t_0/T_2$$
$$= \pm 0{\cdot}6\ \lambda_2/L_2,$$

where λ_2 is the effective cam length and L_2 the roller circumference. The effective cam length is the length of the cam referred to a radius of rotation equal to the roller radius.

The measured slip is then:

$$\frac{M L_1 - N L_2}{M L_1} \pm (0{\cdot}5\ \lambda_2/L_2) \cdot (L_2/M L_1),$$

where L_1 is the circumference of roller 1,

$$= \frac{ML_1 - NL_2}{ML_1} \pm 0{\cdot}6\ \lambda_2/NL_2$$

very nearly, since $NL_2 \approx ML_1$.

The error in those cases when τ is appreciable, or when repeated coincidences occur will be less than this, in the former tending to a limit two-thirds as great (if $t_0 = 3\tau$ at the highest speed), and in the latter being approximately $1/n$ as great, where n is the number of coincidences in a group.

For a cam with an effective length of $1\frac{1}{2}$ inches on a roller of 25 inches circumference $\lambda_2/L_2 = 0{\cdot}06$, and at 100 yards/minute t_0 has a value of 25msec. The error is $\propto = 0{\cdot}036/N$, and hence for $N > 36$ $\propto < 0{\cdot}1$ per cent. A smaller value than this is probably unnecessary in view of the errors in the measurement of L_1 and L_2. If required the manual control can be used to obtain a sufficiently high value of N.

Acknowledgments

The author wishes to thank the Director of the British Cotton Industry Research Association for permission to publish this article.

REFERENCES

1. See for example— SWIRE, B. E. Relay Scaling Circuits. *J. Sci. Instrum. 29*, 339 (1952).
2. CRAMER, H. Mathematical Methods of Statistics. 244 (Princeton University Press, 1951).

D.C. Amplifiers

Methods of Amplifying and Measuring Small Direct Currents and Potentials

(Part 3)

By J. Yarwood*, M.Sc., F.Inst.P., and D. H. Le Croissette†, M.Sc.

The Use of Receiving Valves in Electrometer Circuits

The specially designed electrometer valve, which has been discussed previously, operates with the lowest grid current that has so far been achieved. This type of valve should therefore be used when extremely low currents are to be amplified. When the grid current limitations are not quite so stringent, however, it is possible to use valves in the commercial receiving range, operated at reduced potentials. With careful selection of certain valve types it is possible to approach the performance of specially designed electrometer valves.

For some applications receiving valves have advantages over electrometer valves. Hay[6] points out that the design of portable battery operated directly coupled amplifiers for the measurement of ionization current requires valves which are small and light, with a low power consumption. Until recently, when miniature and sub-miniature electrometer valves became available, the existing valves in the electrometer range were of comparatively large physical dimensions.

By comparing values for the amplification factor given in Table 1 to values given previously for electrometer valves, it can be seen that certain selected receiving valves would provide more gain in electrometer circuits. Provided the higher grid current can be tolerated, the increased output of the first stage of an amplifier allows the following stage to operate at a higher level, with a corresponding relaxation of the drift and grid current considerations which would otherwise apply.

* *The Mathematics and Physics Department, The Polytechnic W.1.*
† *The Physics Department, The University of Southampton.*

TABLE 1.
Operating conditions of receiving valves suitable for electrometer use

VALVE	i_g (A)	V_a (V)	I_a (μA)	V_{g2} (V)	V_f (V)	I_f (mA)	g_m (μA/V)	μ	R_a (MΩ)	REMARKS	REFERENCE
RCA 954	10^{-13}	30	12	3·0	4·0	—	—	—	—	Stage gain = 2.2	Harris[65]
RCA 954	3×10^{-16}	4·8	6·0	4·5	3·0	—	30	—	—	$V_{g1} = +0.5$V electrometer connexion	Hay[6]
RCA 955	5×10^{-12}	36	60	—	4·0	—	130	25	0·2	—	Bishop[63]
Brimar 1C5GT	10^{-13}	16·5	20 to 100	—	1·0	60	300	—	—	Triode connexion. Current amplifier	Hay[6]
Brimar 3S4	10^{-14}	6·0	7·0	10·5	0·7	30	—	150	1·5	Half filament in use	Hay[6]
Brimar 3S4	2×10^{-14}	6·0	80	12·0	1·4	30	150	—	—	Current amplifier	Hay[6]
—12BE6	5×10^{-14}	12·0	—	7·5	—	105	—	250	—	—	Anker[64]
RCA 959	$1{\cdot}7\times10^{-15}$	6·0	21	6·0	0·5	—	20	—	—	$V_{g1} = +0.5$V Electrometer connexion	Nielsen[7]

Several workers have investigated the receiving valve range in order to find suitable types of valve for this application[6,7,36,61,65]. Table 1 gives operating conditions of a number of such valves.

Hay[6] and others have noted that two distinct types of valve are often required. One is a voltage amplifier for use as the input stage. It must have a low value of grid current and as high a value of amplification factor as is possible. The other type is a current amplifier which may be operated as an output valve or in a single valve amplifier where high sensitivity is not required. In neither of these latter applications is extremely low grid current essential.

The characteristics necessary in commercial receiving valves for this purpose are similar to those of an electrometer valve.

(1) Low and constant grid current.

(2) Stability of characteristics with time.

(3) Low surface leakage.

(4) Replaceability.

Valves for the Amplification of Currents Greater Than 10^{-11}A

Many commercial receiving valves may be used in this range. Both triodes and pentodes are suitable. The use of H.T. potentials below 40 volts considerably reduces the grid current; it is also usually advisable to operate the valve at a reduced heater voltage. When pentodes are in use the anode potential should be less than that of the screen since the grid current is substantially reduced under these conditions[63].

Selection of valves is necessary if the lowest grid current is required since the variation between valves of the same type is considerable.

Valves for the Amplification of Currents Less Than 10^{-11}A

Grid currents in certain receiving valves may be reduced almost to values obtained by the best electrometer valves, i.e. to about 10^{-14}A. The precautions necessary for the use of these valves are generally the same as for electrometer valves. Some additional care must sometimes be taken since the valves are being used for a purpose for which they were not designed. The precautions will be considered in turn.

(1) The use of low anode, screen and heater volts.

(2) Screening from light and stray fields.

(3) Reduction of surface leakage.

(4) "Electrometer connexion".

(1) THE USE OF LOW ANODE, SCREEN AND HEATER VOLTS

It is advisable to operate all receiving valves used for low current amplification at a lower heater voltage. This reduces positive ion emission and also reduces photo-electric current produced by light from heater and cathode. Direct current should be used and the potential of the heater should be slightly positive with respect to the cathode, if possible. This is to prevent any electrons which may be emitted by the heater itself from being collected by the control grid.

Low anode and screen volts should be used, as for electrometer valves, to ensure that the electron energy on approaching the anode is less than the amount required for ionization of the residual gas. The valve characteristic must be such that a high enough anode current exists for the purpose required, even when the anode voltage is low. Where a fairly large anode current is desired, anode and screen potentials may be increased only at the expense of increased grid current.

(2) SCREENING FROM LIGHT AND STRAY FIELDS

All valves should be operated in complete darkness when very low grid currents are desired[7]. Stray electric or magnetic fields are to be avoided since any change in the strength or position of the field affects the output of the stage. Johnston[44] discusses electro-magnetic and electrostatic pick-up in balanced stages.

(3) REDUCTION OF SURFACE LEAKAGE

Where the input impedance of a commercial valve is required to be high, of the order of $10^9\Omega$ or greater, it is necessary to clean the valve thoroughly. For single ended valves the bakelite valve base, if present, should be removed and the valve washed in alcohol. A coating of paraffin wax may be applied to the glass after cleaning or a high quality moisture resistant varnish used[62,64]. Hay[6] suggests using a silicone coating in the following manner. The valve is washed in alcohol and ether and then allowed to stand in a humid but clean atmosphere for a day. This is necessary, as the formation of a silicone water repellant film is dependent on an initial film of water. The valve is then supported in a large air-tight jar, and an uncorked bottle of B.T.H. "Teddol" placed in the jar for 20 minutes. Vapour from the bottle then reacts with the moisture to form a closely adhering water repelling film. This method gives an insulation between pins of a B7G base greater than $10^{15}\Omega$.

(4) "ELECTROMETER CONNEXION"

It is sometimes possible to use an electrode in a commercial valve in the same way as a space charge grid in an electrometer valve. The valve is then termed "electrometer connected". This connexion has been used in particular with the acorn valves 954 and 955[7,65,66]. These valves, by virtue of their wide pin spacing, are ideally suited for use as low current electrometer valves. Grid g_2 is used as the space charge grid and g_3 as the control grid. It is usual to apply a small positive potential of between 0·2 and 1·0 volts between g_1 and the cathode. Varying this potential gives some control over the characteristics of the valve which is an advantage if the valve is used in a balanced circuit. As in a specially designed electrometer valve, the use of a space charge grid reduces the control grid current

The use of an electrometer connected acorn pentode has the disadvantage that the input capacitance is higher than when g_1 is used as control grid. However, this connexion is advantageous if an extremely low grid current is required[65]. Nielsen[7] notes that all acorn valves tested had a grid current of less than 10^{-14}A when electrometer connected.

Interstage Coupling

Harris and Bishop[40] have reviewed the methods of interstage coupling with particular reference to balanced amplifiers. The methods which are mainly used fall in three categories.

(1) Potential divider coupling.

(2) Backing off methods.

(3) Use of a valve in the divider network.

(1) POTENTIAL DIVIDER METHODS

Direct anode to grid connexion and the use of a divider network, with or without bias, are in this category. When battery supplies are being used it is often possible to supply a low anode potential to the first stage, and couple this anode directly to the following grid. The cathode of the second stage may be returned to a tapping on the battery so that a suitable bias is obtained. Using direct anode to grid coupling in this way, an amplifier can be constructed having a voltage gain of 80db using a 250V H.T. supply[39,40].

The use of a potential divider with negative bias is shown in Fig. 22. This circuit may be arranged so that, with zero input, the grid potential of the second stage is also zero. Although the gain per stage is reduced in this method, it is possible to use any grid in an amplifier con-

structed on these lines as an input terminal, and servicing is made easier.

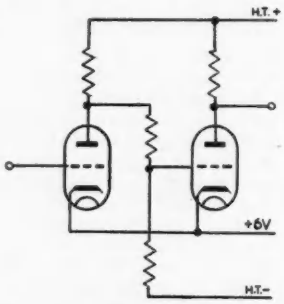


Fig. 22. Use of a potential divider with negative bias for interstage coupling

(2) BACKING OFF METHODS

It is possible to use a battery connected between the anode of the first stage and the grid of the second stage. In this way a low grid potential may be achieved while retaining direct coupling. This method has been used in low gain, battery-operated amplifiers. For the final stages a glow discharge tube may be used in place of the battery[45,39,40]. The operating current, which may be as low as 100μA, is obtained via the anode load of the previous stage.

(3) THE USE OF A VALVE IN THE DIVIDER NETWORK

The use of a valve has been suggested to replace the grid resistance in the potential divider network. Mezger[45] uses a triode, and Bishop[63], using a pentode, shows that the attenuation produced is only 5 per cent of the total signal. As in the use of valves as cathode loads, a high differential resistance is obtained combined with a low voltage drop across the valve.

Harris and Bishop[40], in assessing the value of the various methods of coupling, consider the use of interstage coupling valves undesirable. They note that glow discharge tubes are more suitable for use in the final stages of an amplifier, whereas in the earlier stages a resistance potential divider is more economical.

Electrometer Input Circuits

When it is necessary to amplify small currents obtained from a high impedance source, a low-grid current input valve is essential. As has been previously mentioned, the use of a high resistance in the grid circuit, combined with the inherent input capacitance of the valve and its associated circuit will often result in a high time-constant which will limit the response of the stage[25,68]. In some circumstances this time-constant may not be excessive, and in these cases, the input valve may be an electrometer operating as a voltage amplifier in the conventional manner. This method of connexion is not suitable, however, when a high speed of response is required. It is found, in addition, that when operating valves with high grid resistances, instability may occur as the value of the resistance increases. Sowerby[69] and Crawford[70] have shown that the use of the input valve as a cathode-follower permits a higher grid resistance to be employed before instability sets in. Furthermore, the effect of the feedback in the cathode-follower is to reduce the effective input capacitance of the valve. If the grid to earth capacitance of the input leads is reduced by connecting the screening on the input cable to the cathode of the valve[71], a very high input impedance combined with an extremely low input capacitance may be obtained. The circuit of such a high impedance balanced stage has been published by Bishop[63], using 954 valves.

Another method of using negative feedback to reduce the time-constant of an input stage has been given by Thomas[68]. Here a two-valve amplifier is used, and feedback is obtained by feeding the output voltage back into the input circuit. Since this results in 100 per cent negative feedback, linearity, stability, and speed of response are greatly increased. The output stage is a cathode-follower which serves not only as a link in the feedback chain but also delivers an output voltage across a low impedance. Since the output and input voltages are identical the unit acts as an impedance converter, allowing a robust moving-coil panel meter to be operated.

Several other circuits for this purpose have been given[72,73,65].

Noise and Drifts

The sensitivity of a directly-coupled amplifier may be increased until the electrical noise level is easily discernible in the output. Further increase is unprofitable, since a signal may only be detected when its magnitude is sufficient to bring it appreciably above the noise level.

Using balanced circuits and stable supplies, amplifiers having very high sensitivities have been constructed[74,75,43]. The problem of electrical noise is of great importance in the design of such amplifiers.

Noise in directly-coupled amplifiers consists of several components[75,40].

(1) Thermal agitation noise of resistors.

(2) Shot noise of the anode current.

(3) Partition noise.

(4) Shot noise of the grid current.

(5) Flicker noise.

(6) Component noise and supply drift.

(1) The thermal agitation noise of resistors may be given in terms of the mean square voltage fluctuation ΔE^2 which is produced by the resistance.

$$\Delta E^2 = 4RkT.\Delta f$$

where R = value of the resistor over the frequency band Δf.

k = Boltzmann's constant.

T = Absolute temperature.

(2) Shot noise of the anode current can be represented by:

$$\Delta I^2 = 2eI_aG^2.\Delta f$$

where e = electronic charge.

I_a = anode current.

G = space charge screening factor, a factor varying from 0·1 to 0·01, representing a reduction in anode shot noise due to the presence of space charge. ΔI is the R.M.S. value of the variation of I_a.

(3) Partition noise is the noise in a pentode due to the splitting of cathode current between anode and screen.

(4) Shot noise of the grid current is given by the following expression:

$$\Delta E^2 = 2eI_gR_g^2.\Delta f$$

where R_g = value of the grid resistor over a frequency band Δf.

I_g = grid current.

and ΔE^2 = mean square voltage fluctuation produced by the grid current.

All the above four sources of noise have a constant frequency spectrum.

(5) At low frequencies, flicker noise is very prominent[75]. The origin and magnitude of this noise has not yet been fully investigated, but the noise is thought to be best

represented by an expression of the type[78]:

$$\Delta I_o^2 = \frac{I_o^3}{\omega^2 + a^2}$$

where I_o = cathode current

$\omega = 2\pi \times$ frequency

a = constant

and ΔI_o^2 = mean square fluctuation of the cathode current due to flicker effect.

It can be seen that flicker noise is of great significance at low frequencies and, as the frequency is reduced, the magnitude of the noise approaches a uniform value. The flicker noise of the input valve assumes great importance in directly coupled amplifiers of high sensitivity.

Flicker effect is thought to be due to variations in contact potential of the cathode surface[40]. Measurements[78] have shown the value of flicker noise to be equivalent to an input of the order of 50 to 100μV.

(6) Component noise includes noise due to poor contacts, microphony and pick-up[44]. All of these types of noise are avoidable by good design and care in building the amplifier. Semi-conducting resistors also introduce a noise voltage and should not be used.

Drifts which occur in the supply voltages have the same effect as very low frequency noise[43]. It is possible to correct partially for these drifts by using an arbitrary zero as was done by Hafstad[74]. This is only suitable, however, when the drift is of constant magnitude and it is very difficult to achieve over a long period.

Complete Amplifiers

From the information which has been gathered here it can be seen that, with careful design, it is possible to build

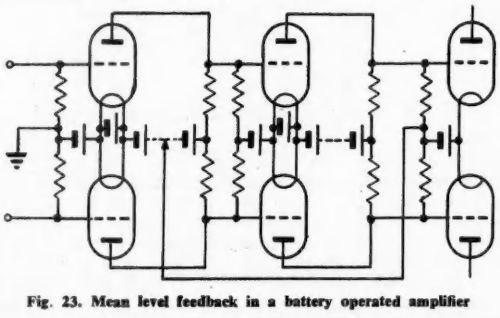


Fig. 23. Mean level feedback in a battery operated amplifier

directly coupled amplifiers having stability and performance approaching the limitations set by random noise. In order to achieve an amplifier of high sensitivity and good performance it is necessary to select valves and components with extreme care. The choice of valves for the input circuit has been treated extensively in view of its importance on the performance of the amplifier. All the valves in the amplifier, however, should be selected with care since their characteristics must remain constant over long periods of time if amplifier stability is to be achieved. Before the final adjustment of any balancing controls it is advisable to age the valves by continuous running.

Semi-conducting types of resistor should be avoided, owing to the high noise which they produce and wire-wound resistors should be used wherever possible. All resistors should be of ample rating so that local heating in the amplifier is avoided.

It has been shown that the use of a balanced stage allows some compensation for variations in supplies to that stage. Thus a balanced amplifier will be inherently less dependent on supply variations than an amplifier containing only single-sided stages. Most of the high gain amplifiers which have been constructed in recent years are of the balanced type.

The use of negative feedback will result in greater linearity and stability. This is true whether single-sided or balanced stages are employed. In the case of balanced amplifiers, however, it is possible to apply negative feedback in two ways.

In the discussion of the balanced stage it was shown that, provided the gain ratio were not zero, any in-phase signal applied to the two valves in the first stage would alter the mean operating potential of succeeding stages. This implies that the in-phase signal is passed on from one stage to the next. Although the amplification of the in-phase signal is usually considerably below that applying to out-of-phase signals, the value of the in-phase input is often quite high. Thus the alteration in the mean operating potential of the output stages of the amplifier due to the in-phase component may be sufficient to disturb the operating conditions of the stages.

Each stage will normally be designed to have as low a gain ratio as possible, so that the combined in-phase gain of the amplifier is low. It is then good practice to introduce 100 per cent mean level negative feedback throughout the amplifier. In this way the operating potentials of all the valves are hardly changed even in the presence of a strong in-phase signal.

Fig. 23 shows the method used by Nielsen[77] to achieve 100 per cent mean level feedback in a battery operated amplifier. The feedback circuit is completed by the lead from the centre-tapped grid resistor of the final stage to the H.T. battery of the first stage. Nielsen shows that the position of the tap on the battery is not very critical. In this way the discrimination factor may be much increased.

Offner[78] has discussed the application of mean level feedback in cathode coupled amplifiers and Johnston[44] and Harris and Bishop[39] have given circuits suitable when mains operated power supplies are in use.

It is advisable to apply the 100 per cent mean level feedback independently of any signal feedback necessary to improve the performance of the amplifier.

In order to eliminate high frequency instability when signal feedback is used, a capacitor may be shunted across the signal path. In this way, marked phase shift at high frequencies, which would cause instability, is avoided.

Further designs of directly coupled amplifiers are considered by Dickinson[79], Goldberg[80], Shepard[81] and Peirson[29].

REFERENCES

61. Reese, H. Design of Vibrating Capacitor Electrometer. *Nucleonics 6*, 40 (1950).
62. Mapplebeck, R. H. Moisture in Electrometers. *Electronic Engng. 23*, 275 (1951).
63. Bishop, P. O. A High Impedance Input Stage for a Valve Amplifier. *Electronic Engng. 21*, 469 (1949).
64. Anker, H. S. Stabilised D.C. Amplifier with High Sensitivity. *Electronics 20*, 138 (June, 1947).
65. Harris, E. J. An Electrometer Impedance Convertor. *Electronic Engng. 23*, 109 (1951).
66. Gabus, G. H., Pool, M. L. A Portable Photo-tube Using an R.C.A. 954 Tube. *Rev. sci. Instrum. 8*, 196 (1937).
67. Bishop, P. O. A Note on Inter-stage Coupling for D.C. Amplifiers. *Electronic Engng. 21*, 61 (1949).
68. Thomas, H. A. Electrometer Input Circuits. *Electronics 19*, 130 (Dec., 1946).
69. Sowerby, J. McG. A Photo-electric Photometer for Measuring the Light Scattered by the Surface of a Transparent Material. *J. sci. Instrum. 21*, 42 (1944).
70. Crawford, K. D. E. H.F. Pentodes in Electrometer Circuits. *Electronic Engng. 20*, 227 (1948).
71. Attree, V. H. Reducing the Effect of Capacitance in Screened Cable. *Electronic Engng. 21*, 100 (1949).
72. Vance, A. W. An Improved Vacuum Tube Microammeter. *Rev. sci. Instrum. 7*, 489 (1936).
73. Downing, J. R., Mellen, G. A Sensitive Vacuum Gauge with Linear Response. *Rev. sci. Instrum. 17*, 218 (1946).
74. Hafstad, L. R. The Application of the FP54 Pliotron to Atomic Disintegration Studies. *Phys. Rev. 44*, 201 (1933).
75. Harris, E. J., Bishop, P. O. Low Frequency Noise from Thermionic Valves Working Under Amplifying Condition. *Nature 161*, 971 (1948).
76. Macdonald, D. K. C. The Brownian Movement and Spontaneous Fluctuations of Electricity. *Research 1*, Pt. 5, 194 (1948).
77. Nielsen, J. O. Eine Methode zur Verbesserung der Nullpunktstabilität von mehrstufigen Gegentakt-Gleichstromverstärkern. *Z. Phys. 107*, 192 (1937).
78. Offner, F. Push-Pull Resistance Coupled Amplifiers. *Rev. sci. Instrum. 8*, 20 (1937).
79. Dickinson, C. J. Electrophysiological Technique (Electronic Engng. Monograph, 1950).
80. Goldberg, H. A High-gain D.C. Amplifier for Bio-electric Recording. *Trans. Amer. Inst. Elect. Engrs. 59*, 60 (1940).
81. Shepard, W. G. High-gain D.C. Amplifier. *Electronics 20*, 138 (Oct. 1947.

The Use of
Cold Cathode Counting Tubes in Cascade

By D. T. Whelan*

Circuits for connecting cold-cathode counting tubes (Dekatrons) in cascade, which will allow the passage of a carry pulse to the next higher valve in the train, and which will initiate a resetting, or zeroing, operation are considered. A circuit to eliminate interference between carry and resetting operations is developed.

AT various times during recent years, articles have been published[1,2] describing the applications of cold-cathode counting tubes (Dekatrons). The connexion of Dekatrons in cascade presents difficulties in that a carry makes necessary a cumbersome circuit for resetting or zeroing. "Carry" is understood as the operation of transferring a pulse from the Dekatron registering "units" to that registering "tens," at the conclusion of one cycle of the "units" tube. Similarly, carry pulses are required to be transferred between each Dekatron and the one following it in the next higher position in the train. "Zeroing" or "resetting" is the operation of forcing the count back to its original starting position before the beginning of a new calculation. It is one of the more attractive features of these tubes that this operation can be carried out without loss of time.

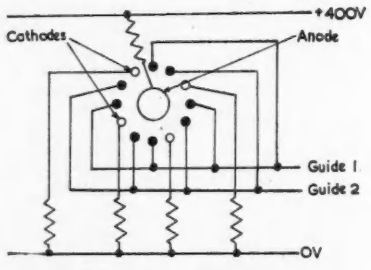


Fig. 1. Schematic diagram of Dekatron

It will be as well, perhaps, to consider first of all the circuit used to drive a Dekatron. A schematic diagram of one such tube is shown in Fig. 1. In its quiescent state there will be a glow discharge between one of the cathodes and the anode. The guides, which are in two groups, are held at a point more positive than the cathodes (at about + 60V). If a large negative pulse is applied to the guide 1 line, such that the guides in this group become more negative than the cathode, the discharge will become centred on that guide, connected to this line, which is adjacent to the cathode concerned. At the conclusion of the pulse, the discharge will move back to occupy the cathode, but if, before the pulse has ended, a second similar pulse is applied to the guide 2 line, the discharge will spread to the adjacent second guide, and at the end of guide 1 pulse the discharge will invest the second guide. At the end of the second pulse the discharge will step to the nearest most negative point, which is the adjacent cathode, and will thus have moved one step. In Fig. 1, four cathodes only are shown, but in fact there are available a variety of such tubes, among them being ten- and twelve-cathode types, for use in decimal or duodecimal counting. The type used in the circuits to be described is the GS10B, a cold-cathode selector tube with ten cathodes, each cathode connexion being separately brought out to a tag on the valve base. The principles of operation, however, apply equally to other types of selector tubes in this range.

A published circuit[3] employs a cold-cathode trigger tube (GTE175M), both as an input trigger and as a coupling valve. This circuit is shown in Fig. 2, where the anode resistor of the trigger tube is tapped and two points are connected via capacitors to the guides of the Dekatron to be driven. The total value of the resistance in the anode circuit of the trigger tube is such that insufficient current will flow to maintain ionization of the trigger unless supplemented by the discharge current of the two capacitors. When the coupling tube is triggered, the capacitors will discharge and the trigger tube will then extinguish. Due to the differing capacitances of the two capacitors and their positions in the anode circuit of the trigger, a larger negative pulse will be passed to the guide 1 line of the succeeding Dekatron, whose discharge will step to the guide connected to this line. Since the time-constants of the capacitive couplings to the Dekatron guides will differ, the charging of the capacitor in the guide 1 line will be more rapid than that of the capacitor in guide 2 line, with the result that the potential of guide 1 line will rise until it reaches a point when guide 2 line is the more negative, when the discharge of the Dekatron will step to guide 2. When both capacitors are charged, the Dekatron discharge will pass to the adjacent cathode, and will have completed one step.

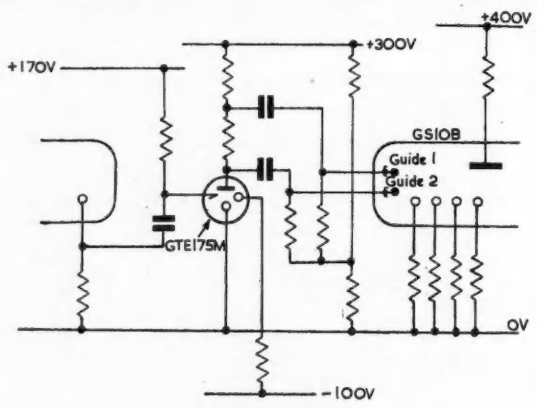


Fig. 2. Carry circuit

To fire the coupling tube, pulses of approximately 25V are applied to the trigger electrode via a 0·001 μF capacitor. The tube will then fire at the positive-going end of the pulse. Consider the circuit shown in Fig 2. Assume that the cathode shown in the left-hand Dekatron becomes occupied by the discharge, which then steps off to the next cathode. Fig. 3 shows the variation in potential which will occur

* *The British Tabulating Machine Co. Ltd.*

during this period. The trigger electrode will receive two pulses; one positive-going, as the discharge invests the cathode of the Dekatron to which it is coupled; and the second a negative-going pulse as the discharge leaves the cathode. This means that the coupling tube will fire as the discharge arrives at the cathode concerned.

In a machine employing a decimal counter or accumulator, although it is not necessary that the progression of the count should conform to a conventional decimal notation, it is preferable that it should do so, in order to simplify the use and programming of the machine by an operator. In the conventional notation the digits represented on the "units" and "tens" Dekatrons must bear the following relationship to each other during a simple count:

Tens :	0 0 0 0 0 0 0 0 0 0 1 1 1
Units:	0 1 2 3 4 5 6 7 8 9 0 1 2 etc.

It will be seen, therefore, that the point at which a carry pulse is required lies between the times when the "9" and "0" cathodes are invested by the discharge. Since the carry pulse will be effective as the discharge arrives at the cathode, then in Fig. 2, the cathode to which the carry or coupling tube is connected must be the "0" cathode of the Dekatron.

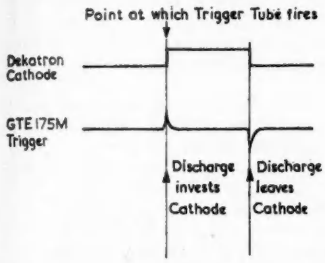


Fig. 3. Variation of potentials in carry circuit

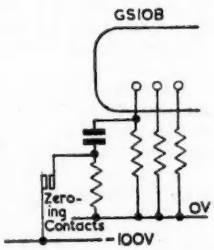


Fig. 4. Zeroing circuit

When a Dekatron circuit is initially switched on, any anode-cathode gap may break down and the glow discharge may occupy any cathode. The same condition obtains at the end of a calculation, when a total of unknown magnitude may be registered in the counter. Before commencing any calculation it is necessary that the count registered by a train of Dekatrons should be brought to a fixed datum. In the case of a multi-stage counter this is conveniently a succession of "0 0 0 0 0—." To bring about this result it is possible to employ a "zeroing relay," whose contacts are arranged to force the discharge to occupy one particular cathode of each Dekatron. Fig. 4 shows a typical resetting or zeroing circuit, in which the operation of the contact connects a large negative pulse to the chosen cathode, and forces the glow discharge to jump to it. Upon removal of the pulse, the discharge will remain at this position.

To obtain a series of 0's the resetting pulses must be connected to the "0" cathodes of the Dekatrons. If the carry or coupling trigger is also connected to this point care must be taken to ensure that the resetting is done cyclically or the operation of resetting will cause a carry pulse to be transmitted to the next higher order in the chain, and a true reset will not result. Resetting in this manner can be accomplished by the zeroing contacts making one after another from the lowest order upwards through the train, but this entails either an involved circuit or a specially adjusted zeroing relay, whose contacts operate in the required order. Neither of these alternatives was regarded with favour, and instead it was decided to use the "9" cathode to initiate a carry transfer, in lieu of the "0" cathode.

In order to maintain the conventional notation in the operation of the counter, the trailing negative pulse shown in Fig. 3. generated as the glow discharge leaves the "9" cathode, is used to cause a carry transfer. This is accomplished by inserting a phase invertor between the carry cathode and the coupling tube, as shown in Fig. 5. The choice of type of valve used for this purpose is dictated in the case of the circuit shown by the interests of standardization, and, in fact, any suitable valve may be used to obtain the conditions shown in Fig. 6. This diagram shows the inversion of the pulse from the "9" cathode, and its application to the trigger tube. It will be seen that a carry pulse is transferred as the discharge leaves the "9" cathode, which satisfies the condition, before described, that this pulse should occur between "9" and "0."

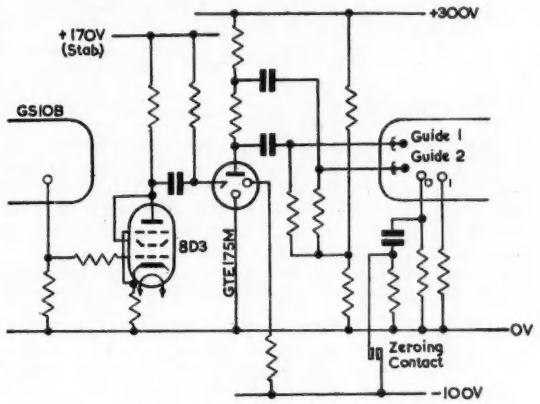


Fig. 5. Carry and zeroing circuit

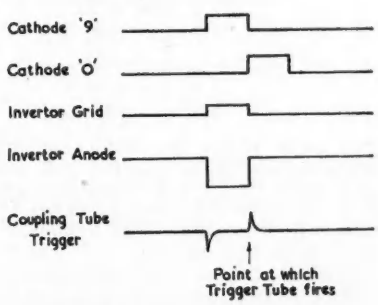


Fig. 6. Variations in potentials in carry circuit when an invertor is fitted

An alternative method which is applicable to a two-stage accumulator or counter dealing only with tens and units is to arrange to start the count at 1 instead of 0, i.e., the normal reset registration is 01. In this case the carry coupling tube is connected to the "0" cathode of the "units" Dekatron, the invertor stage being omitted. This ensures that a spurious carry pulse is avoided by removing the reset pulse circuit from this cathode and connecting it instead to the "1" cathode. For many purposes it is advantageous to use this 01 condition as a datum, but where there are more than two Dekatrons in cascade, all those above the units position must reset to 0, and invertor stages will be required in all but the "units-tens" carry position.

Acknowledgments

The author would like to express his thanks to the British Tabulating Machine Company Limited, by whose permission this article is published.

REFERENCES

1. Bacon, R. C., Pollard, J. R. The Dekatron. *Electronic Engng.* 22, 173 (1950).
2. Barnes, R. C. M., Cooke-Yarborough, E. H., Thomas, D. G. A. An Electronic Digital Computor. *Electronic Engng.* 23, 286 (1951).
3. Cold Cathode Tubes Handbook. (Ericsson Telephones Ltd.).

A Low-Pass Filter with a Continuously Variable Cut-off Frequency

By J. W. Thompson*, B.Sc., A.M.I.E.E.

An electronic feedback system having characteristics similar to those of a conventional low pass filter is described. The cut-off frequency can be continuously changed over a wide range by a simple control. A detailed electrical circuit is given, and calculated and measured frequency response curves are shown.

THE suppression of electrical disturbances which interfere with submarine cable telegraph signals when electronic receiving apparatus is in use has recently been under investigation. The greater part of the energy of a particular form of disturbance lies in a frequency band above that necessary for adequate signal definition, and the signal-to-noise ratio can therefore be improved by a low-pass filter. The cut-off frequency should be adjusted for each individual case to give the best compromise between signal definition and noise rejection, and for this reason it is desirable to have a filter whose turning point may be continuously varied. Adjustment should be possible over the range 10c/s to 60c/s. This is difficult to achieve with a conventional *LC* network.

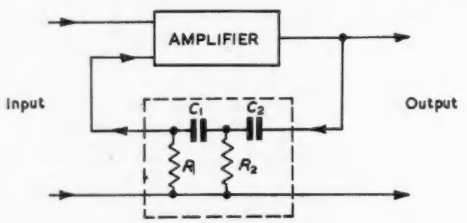


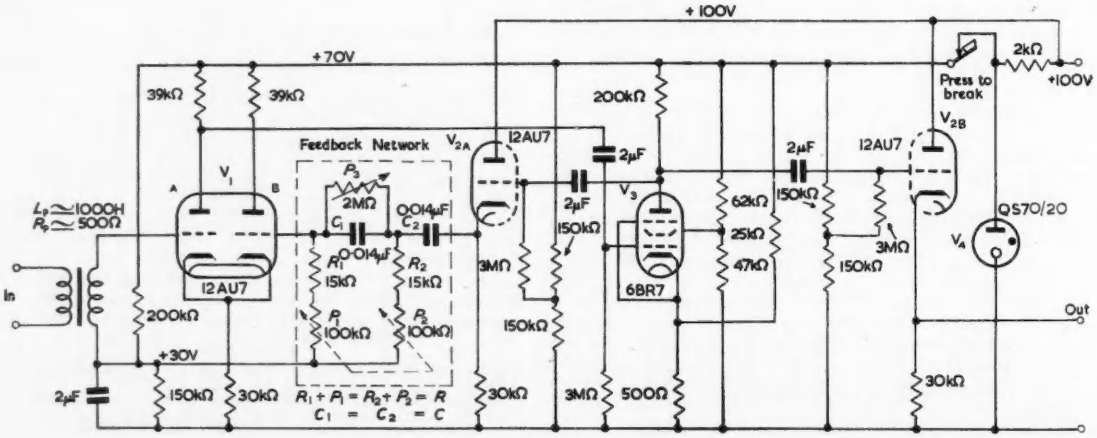
Fig. 1. Feedback network

A type of feedback amplifier which can have characteristics similar to those of a low-pass filter, and which can easily be arranged to have a variable cut-off frequency, has been described by Miller[1] and is shown in schematic form in Fig. 1. An inherent feature of this device is a frequency response which rises immediately before cut-off, thus producing a transient characteristic which is unsuitable for some purposes unless an equalizing network is used at a later stage.

An alternative method of levelling the pass-band response and improving the transient characteristic is to shunt capacitor C_1 in Fig. 1 by a resistor. It can be seen by inspection that the value of the resistor may be chosen so that it seriously modifies the transfer characteristic of the feedback network only in the region of cut-off, for its effect is masked by the low reactance of C_1 at high frequencies and by the high reactance of C_2 at low frequencies. The calculation of the response of the feedback amplifier both without and with the additional shunting resistor is shown in the appendix, and the calculated curves are plotted in Fig. 3 (Curves G and H).

The electrical circuit of a low pass *RC* amplifier filter which has been constructed on these lines is shown in Fig. 2. A transformer with a time-constant of about one second is used to couple the input signal to the grid of V_{1a} where it is amplified and fed to the grid of V_2. The output voltage from the anode of V_3 is fed back to the grid of V_{1b} via the cathode follower V_{2a} and the feedback network. The turning point of the frequency response curve may be

Fig. 2. RC amplifier filter



* *Cable and Wireless Ltd.*

continuously changed by rotation of the ganged potentiometers P_1 and P_2. The transient response can be modified by adjustment of P_3. The output of the unit is taken from the anode of V_3 via a second cathode follower, V_{2b}. The filter has been designed for a 100 volt supply and it is therefore necessary to operate the "press to break" switch to ensure that V_4 is struck.

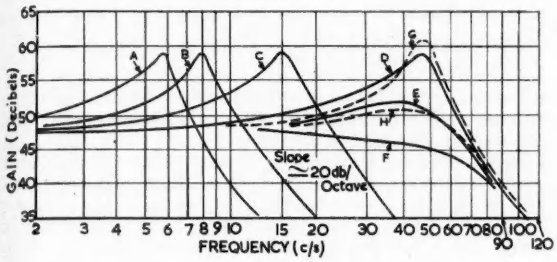


Fig. 3. Response curves

C=0·014μF μ=250 ; *Full line-measured, dotted line-calculated*

CURVE	SETTING OF P_1+P_2	P_3
A	0 (R=115kΩ)	∞
B	40 (R= 75kΩ)	∞
C	75 (R= 40kΩ)	∞
D	100 (R= 15kΩ)	∞
E	100 (R= 15kΩ)	400kΩ
F	100 (R= 15kΩ)	150kΩ
G	*calculated ; parameters as for* D	
H	" " " " E	

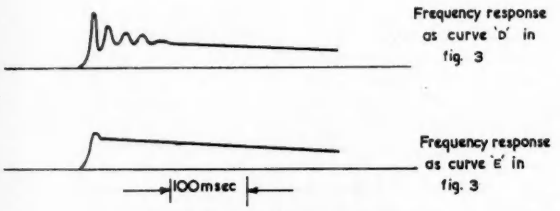


Fig. 4. Observed transient response

A family of measured frequency response curves is shown in Fig. 3. Curves A, B, C, and D were obtained with different settings of P_1 and P_2 when P_3 was disconnected. Curves E and F illustrate the effect of P_3 for the case where the other parameters correspond to curve D. Tracings from photographs of the response to unit function input, obtained with filter characteristics shown by curves D and E, are given in Fig. 4. Curves A, B and C, together with their associated transient characteristics, are changed in a similar manner by adjustment of P_3.

Acknowledgment

The author wishes to thank the Engineer-in-Chief, Cable & Wireless Ltd, for permission to publish this article.

APPENDIX

CALCULATION OF FREQUENCY RESPONSE (Fig. 5)

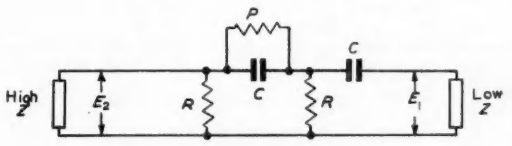


Fig. 5. Equivalent feedback circuit

Let β = the proportion of the output voltage which is fed back ($= -E_2/E_1$).

μ = the gain of the amplifier without feedback (measured from grid of V_{1a} to anode of V_3).

G = the gain of the amplifier with feedback.

θ = argument β.

From the mesh equations for the equivalent feedback circuit it can be shown that:

$$\beta = \frac{(1 + b^2)}{(a^2 - b^2 - ab - 1) + j(3a + 2ab^2 + a^2b)}$$

where $a = 1/\omega CR$ and $b = 1/\omega CP$.
When P becomes infinite this reduces to:

$$\beta' = \frac{1}{(a^2 - 1) + j(3a)}$$

The values of β and β' were calculated at different frequencies with:

$C = 0{\cdot}014\mu F$
$R = 15k\Omega$
$P = 400k\Omega$

The determination of the overall gain for a given value of β was facilitated by the use of a chart[2]. The theoretically derived response curves for $\mu = 250$ are shown dotted in Fig. 3 (G and H) and the results from which they were plotted are given in Table 1.

REFERENCES

1. MILLER, C. H. R-C Amplifier Filters. *Wireless Engr.* 27, 26 (1950).
2. FELKER, J. H. Calculator and Chart for Feedback Problems. *Proc. Inst. Radio Engrs.* (October, 1949).

TABLE 1.

								← $P=\infty$ →			← $P=400k\Omega$ →		
f (c/s)	a	b	a^2	b^2	ab	$3a$	$2ab^2$	a^2b	$\lvert\beta'\rvert$ (db)	$\theta°_{\beta'}$	G' (db)	$\lvert\beta\rvert$ (db)	$\theta°_{\beta}$	G (db)
10	75	2·8	5 630	7·8	210	225	1 170	15 800	−75	− 2°	48	−66	−72·5°	48
20	38	1·4	1 440	1·96	53	114	149	2 020	−63	− 4·5°	50	−59	−59°	49
30	25	·94	625	·88	23·5	75	44	590	−56	− 7°	52·5	−54	−50°	50
40	19	·71	362	·50	13·5	57	19	257	−51	− 9°	58	−50	−44°	51
50	15	·57	225	·32	8·5	45	9·6	128	−47	−12°	60	−47	−41°	50·5
60	12·6	·47	158	·22	5·9	38	5·5	74	−44	−13·6°	52	−44	−38°	48
100	7·5	·28	56·3	·08	2·1	22·5	1·2	15·8	−36	−21·6°	38·3	−36	−37°	37·8

$R = 15k\Omega$ $C = 0{\cdot}014\mu F$ $\mu = 250$ (48db)

Step to Frequency Response Transforms for Linear Servo Systems

(Part 3)

By L. C. Ludbrook,* B.Eng., A.M.I.E.E.

Approximate Relations for R.P.C. Servos

Objective and Scope of Rules

A DESIGNER using the step response approach to servo synthesis is concerned with frequency response only as a measure of the undesired amplification given to spurious high frequency signals, and for this restricted purpose a useful indication is given by three salient features of the amplitude response viz: the frequency (F_{max}) and per unit amplitude (Q_{max}) of maximum transmission and the frequency ($F_{0\cdot5}$) of nominal cut-off. It has already been shown that the amplitude response as a function of frequency is independent of the amount of dead time at the "toe" of the step response; for the restricted purpose any dead time is therefore to be disregarded and time zero taken as the instant at which the step response first attains 2-5 per cent of its crest value.

The risk of excessive resonant amplification is only one of several conflicting factors influencing the choice of step response, and in the early stages of seeking the best compromise it would be useful to have an immediate idea of the way in which the three salient features of the frequency response are affected by changes in the shape of the step response. In the present state of the art, the process of synthesis depends largely on engineering judgement and even the basic data is not precise; for example the servo designer usually has to make his own "educated guess" at the spectrum of spurious input signals and the output that can be tolerated in each particular job. In formulating the rules, the objectives are therefore simplicity and speed of use rather than rigorous accuracy; the complete frequency response should be derived for the step response finally chosen, partly as a check on the rules, but mainly to extend the collection of standard forms originated by Whiteley[12]; these standard forms present the data in the most convenient way for practical use, and leave the designer free to concentrate on methods of attaining the chosen linear mode response, and on the problems encountered in the non-linear region.

Q_{max}-A_{max} Relation

The numerical ratio Q_{max}/A_{max} is very much affected by the way in which the curve of step response recovers to unity after the peak of first overshoot. Consider, for example, two limiting cases, each with $A_{max} = 2$ (i.e. 100 per cent overshoot); if the curve of step response remains at the peak overshoot value then Q_{max}/A_{max} does not exceed unity, but if the first overshoot is followed by others of about the same magnitude in an almost undamped oscillatory response then Q_{max}/A_{max} approaches infinity. Thus if Q_{max} is plotted against A_{max} for typical step responses the points will not lie on a single valued curve; it may, however, be possible to define an area containing the points of technical interest and to indicate the trend of distribution within that area. The boundary cases of practical interest appear to be on the one hand a step response with single mode of damped sinusoidal oscillation and on the other hand a step response with monotonic runback to unity from a single overshoot peak.

An *LRC* filter section formally equivalent to the simplest possible "zero displacement error" servo has already been considered; the values of Q_{max} and A_{max} are plotted as functions of damping resistance on Fig. 15, and show that when A_{max} is made greater than 1·2 the ratio Q_{max}/A_{max} exceeds unity and increases very rapidly. Chestnut and Mayer[13] have reached a similar conclusion after computing the responses of a wide range of linear R.P.C. servos and it seems reasonable to regard the Q_{max}-A_{max} relation of Fig. 15 as one boundary line representing systems with single mode damped sinusoidal response to input position step.

The other boundary line for systems with monotonic runback from single overshoot peak may be estimated by

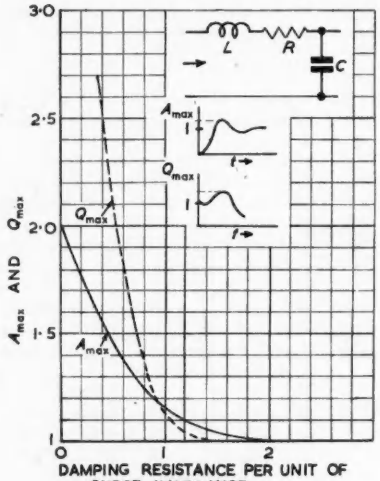


Fig. 15. Q_{max}, A_{max} relation

applying equation (3) to a two segment approximation of the step response and examining the trend as the runback time is varied relative to the build-up time, and as the amount of overshoot is varied. The step responses shown in Fig. 16(a) all reach $A_{max} = 1{\cdot}5$ at one second, but have various runback times T_R between zero and infinity. The corresponding amplitude response curves computed from equation (3) are plotted in Fig. 16(b) as far as the nominal cut-off frequency and show that over the whole range of runback time the ratio Q_{max}/A_{max} lies between 0·73 and 1·09. In practice it is most unlikely that the runback slope will be steeper than the build-up slope and if the lower limit of runback time T_R is taken as 0·5 second, then the spread of the ratio Q_{max}/A_{max} is only 0·9 to 1.09.

In the limiting cases of zero and infinite runback time some unexpected features of the frequency response merit detailed examination; the "build-up vector" $1.5\left(\frac{\sin \pi f}{\pi f}\right)e^{-j\pi f}$ (i.e. originated by the build-up portion of the step response) is common to both cases and its locus is shown as the solid line in the second and third quadrants of Fig. 17(a).

If runback time is zero the "runback vector" $-0{\cdot}5\ e^{-j2\pi f}$ has constant amplitude and rotates in the

* *British Thomson-Houston Co., Ltd.*

$(X_{(f)} + jY_{(f)})$ plane in the same direction and twice as fast as the build-up vector; the locus of the sum of these vectors is shown as the dotted line in Fig. 17(a) up to 1·25c/s and at higher frequencies it becomes a circle of radius 0·5 centred on the origin. It is physically correct that the per unit response should thus have amplitude 0·5 and phase lag increasing at 360°c/s out to infinite frequency because instantaneous runback in the step response of a linear network could only be achieved by subtracting from the output at the correct instant a portion of the input step signal that had been retarded in a side chain; physically this side chain would be a properly terminated delay cable or equivalent magnetic storage device, and would continue to transmit its portion of input signal out to infinite frequency. This is a particular case of the general postulate that if the graph of per unit response of a linear system to step

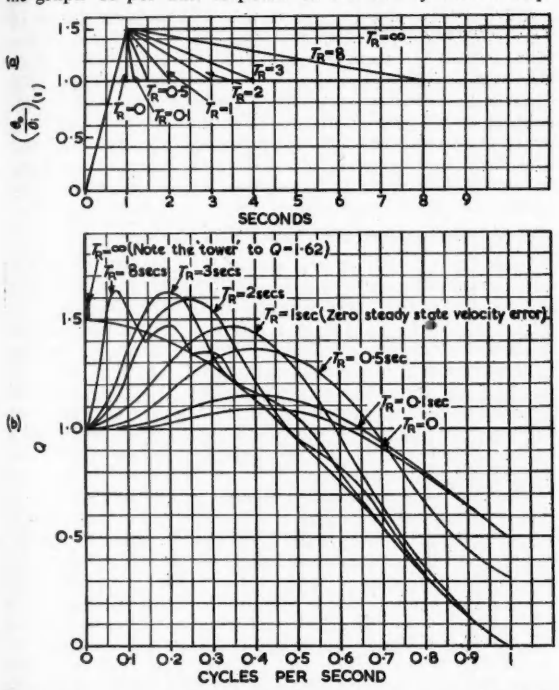


Fig. 16 (a). Two segment approximations to step response with single overshoot to $A_{max} = 1.5$ at 1 second and various values of runback time T_R.
(b) Q curves corresponding to the above single overshoot step responses

function input contains anywhere one vertical rise or fall of amount A then the corresponding per unit amplitude response to sinusoidal input settles to constant amplitude A at high frequencies. If the step response contains two or more vertical segments, transmission is still maintained out to infinite frequency, but the amplitude curve ocillates between two fixed values because the component vector originated by a late vertical segment rotates faster in the $(X_{(f)} + jY_{(f)})$ plane, hence periodically swings in and out of phase with the component vector originated by an earlier vertical segment. Vertical segments in the step response appear to offer no advantage and would not occur in conventional servo systems; they might, however, be inadvertently introduced if finite delay elements were used in side chain feedback circuits as has sometimes been proposed.

Passing to the other extreme of infinite runback time, the locus of the generalized runback vector $-0{\cdot}5\left(\frac{\sin \pi T_R f}{\pi T_R f}\right)e^{-j\pi(T_R+2)f}$ acquires the same geometric shape as that of the build-up vector when T_R becomes very large so that $(T_R + 2) \simeq T_R$, but its initial amplitude is only $-0{\cdot}5$ and it is completely traversed for a very small increment of frequency from zero. The locus of the runback vector for the limit case of $T_R = \infty$ is shown as the solid line in the first quadrant of Fig. 17(a) positioned relative to the locus of the build-up vector so that the vector sum can be scaled off directly from the origin. This limiting runback vector is traversed for a vanishingly small increment of frequency from zero and accounts for the "tower" at zero frequency in Fig. 16(b); the effect is reminiscent of Gibbs[14] phenomenon encountered when summing a Fourier series to reconstitute a discontinuous time waveform.

Fig. 16(b) shows that as T_R the duration of runback slope is increased, Q_{max} is increased and F_{max} is reduced. Insertion of a dwell period (i.e. a horizontal segment) at

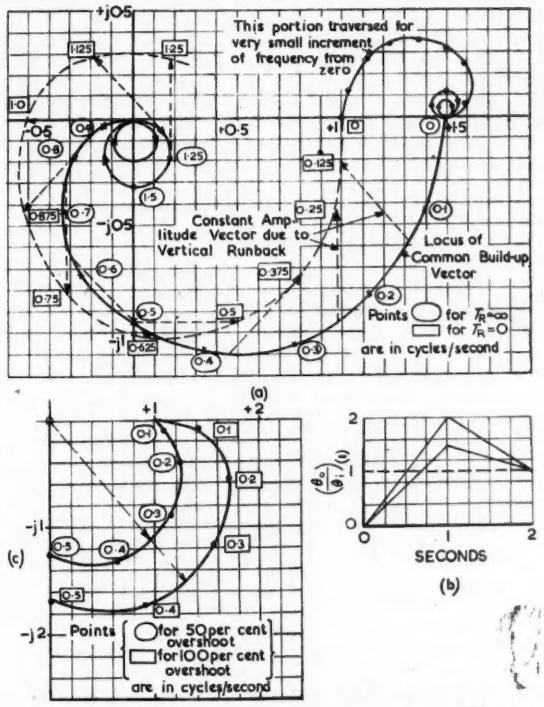

This portion traversed for very small increment of frequency from zero
Constant Amplitude Vector due to Vertical Runback
Locus of Common Build-up Vector
Points for $T_R=\infty$ for $T_R=0$ are in cycles/second
(a)
(c)
Points for 50 per cent overshoot for 100 per cent overshoot are in cycles/second
SECONDS
(b)

Fig. 17 (a). Vector loci for limiting cases of runback times $\begin{cases} T_R = 0 \\ T_R = \infty \end{cases}$
(b). Two segment approximations to single overshoot step response with $\begin{cases} 1 \text{ second build-up time} \\ 1 \text{ second runback time} \end{cases}$
(c). Portions of Vector Loci $\left(\frac{\theta_0}{\theta_i}\right) j\omega$ for the examples of Fig. 17 (b).

peak overshoot before the runback slope gives a similar effect because the faster rotating runback vector then swings round to boost the build-up vector at a lower frequency after less attenuation. In this particular case of $A_{max} = 1{\cdot}5$ the maximum amplitude response approaches $Q_{max} = 2$ as the dwell period is increased; this is intermediate between $Q_{max} = 2{\cdot}32$ given by damped sinusoidal mode and $Q_{max} = 1{\cdot}62$ given by immediate monotonic runback, and the latter case as illustrated in Figs. 16(a) 16(b) appears to define the desired lower boundary for the Q_{max}-A_{max} relation.

Having shown that for these elementary single overshoot step responses the ratio Q_{max}/A_{max} lies between 0·9 and 1·09 over the practical range of runback times, it remains to examine the effect of varying the amount of overshoot. The intermediate case of $T_R = 1$ second is used for this purpose and responses with $A_{max} = 1{\cdot}5$ and $A_{max} = 2$ are shown in Fig. 17(b). The corresponding frequency response loci computed from equation (3) are plotted in Fig. 17(c), and show that the ratio $Q_{max}/A_{max} \simeq 1$ and the resonant frequency

0·35c/s are substantially unaffected by the change from 50 per cent to 100 per cent overshoot.

The foregoing crude approximations applied to a few cases suggest the relation $Q_{max} = A_{max}$ as the boundary line for systems having immediate monotonic runback from single overshoot peak. This is plotted on Fig. 18 together with the earlier relation for systems having a single mode of damped sinusoidal oscillation, and it is seen that almost all the points computed by Chestnut and Mayer[13] do lie in the area bounded by these two lines.

A single overshoot in the step response can suffice to give zero steady state velocity error, but if the time scale cannot be shortened far enough to bring the steady state acceleration error down to an acceptably low value then the overshoot area must be increased and an undershoot introduced. Even if sinusoidal terms are avoided and the overshoot and undershoot are obtained as the sum of simple exponential terms, the general effect of these changes is to increase the ratio Q_{max}/A_{max} as compared to that for the single overshoot case. The build-up vector is little affected, but the runback vector has its initial amplitude increased by the amount of undershoot; its increase of attenuation rate due to the longer duration of runback is relatively small and tends to be offset by its increase of

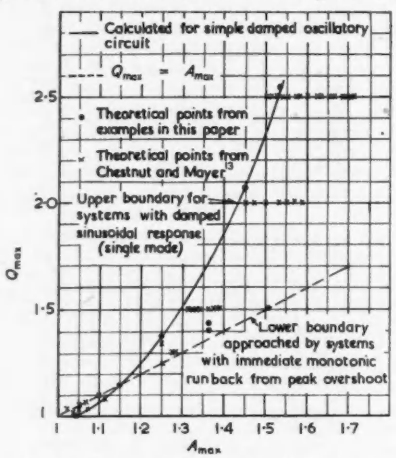


Fig. 18. Relation between Q_{max} and A_{max} for R.P.C. servos

rotation rate due to the later average time of occurrence of runback; the runback vector therefore retains a greater amplitude when it has swung round to boost the build-up vector, and the total amplitude response Q_{max} is correspondingly increased. The third vector, originated by the final run-up segment of the step response from trough undershoot to unity has relatively high rates of attenuation and rotation because the run-up segment is of long duration and occurs late in time; nevertheless this run-up vector may contribute significant extra boost in the region of Q_{max}. Further experience is required on this problem, but the present picture is that Q_{max}-A_{max} points for zero steady state acceleration error systems are likely to lie between the two boundary lines of Fig. 18, and will move nearer the upper boundary as the undershoot amount is increased and duration correspondingly decreased to retain the desired net area.

$F_{0·5} - T_C$ Relation

An existing rule derived by Guillemin[15] for the idealized low pass filter and confirmed by McColl[16] from experience of practical filters indicates that cut-off frequency is about half the reciprocal of build-up time. As build-up time is constant at one second for the idealized single overshoot step responses of Fig. 16(a) the cut-off frequency should, according to this rule, be constant at 0·5c/s, but the curves of Fig. 16(b) show that, over the practical range of runback time, the spread of $F_{0·5}$ is from 0·72c/s to 0·87c/s. This discrepancy is due partly to the different conventions for "cut-off frequency" and "build-up time," and partly to the over simplified nature of the two segment step responses. The effective build-up time in a practical servo response is certainly less than the time to peak of first overshoot and is more nearly equal to T_C the time to first cross correspondence. Bearing in mind that T_C is an important parameter in the synthesis of step responses and that a simple easily memorized rule is sought for a restricted purpose, the suggested relation is that $F_{0·5} = 0·5/T_C$, i.e. that nominal cut-off frequency equals half the reciprocal of the time to first cross correspondence.

$F_{max} - T_C$ Relation

The curves of Fig. 16(b) show that a given cut-off frequency $F_{0·5}$ can be associated with a wide range of values of resonant frequency F_{max}, but the general indication is that for step responses of practical interest F_{max} lies between $0·3F_{0·5}$ and $0·5F_{0·5}$, the lower values being associated with long duration of runback relative to build-up time in the step response. The relation $F_{max} = 0·25/T_C$ is tentatively offered for the restricted purpose but must obviously be applied with discretion and the complete transformation from step response to frequency response carried out in doubtful cases.

Checks Against Responses of Actual Servos

In this section both the graphical transformation method and the tentative rules are applied to some measured step responses of actual servo systems, and the results compared to the measured frequency responses. In addition to the probable non-linear behaviour of practical servos, two sets of experimental errors are introduced, so that it is not possible to segregate the errors due to the graphical approximation and simplified rules. The overall picture is, however, of interest to the practising engineer who needs to know how closely the predictions of linear theory can be approached in fact.

The test results are taken from existing reports on six servos with power ratings between 0·25 h.p. and 5 h.p. R.M.S. and responses ranging from the fastest possible (consistent with the mechanics of a given gun) to deliberately sluggish (for signal smoothing in an early auto-follow radar). While amplitude response was readily measured by observing the peak-to-peak movement of the servo motor shaft, the special equipment needed for measuring phase lag has only recently become available and the existing test reports contain only amplitude response measurements. The tentative rules can be examined over a wide range, but the graphical transformation cannot be completely checked.

Step and Frequency Responses of an Auto-follow Radar

The solid lines of Figs. 19(a) 19(b) show respectively the measured responses to $1°_{(1)}$ and $0·43° \sin \omega t$. The dashed and dotted lines of Fig. 19(a) show respectively four segment and five segment approximations to the measured step response and it should be noted that due to the use of horizontal segments only three component vectors have to be computed in each case. The corresponding amplitude responses plotted as the dashed and dotted lines of Fig. 19(b) show the increase of Q_{max} and decrease of F_{max} caused by introduction of a dwell at peak overshoot as discussed previously. The slight increase of $F_{0·5}$ is due to the slightly steeper build-up slope used in the five segment case.

Predicted and experimental values are compared in Table 1.

This particular system was unusually linear because the deliberately sluggish response (dictated by the associated predictor) was attained by a local negative feedback loop from aerial acceleration to the input of the electronic

amplifier exciting the Amplidyne; there are, however, considerable discrepancies between the results obtained by various methods.

Table 1

METHOD OF FINDING FREQUENCY RESPONSE		Q_{max}	F_{max} (c/s)	$F0{\cdot}5$ (c/s)
Measured direct		1·35	0·25	0·8
From measured Step response	4 segment approx.	1·40	0·35	1·0
	5 segment approx.	1·44	0·30	1·1
	Tentative rules	1·35-1·5	0·42	0·9
Calculated from parameters of idealized system		1·20	0·28	1·2

Q_{max}-A_{max} Relations

Fig. 20 records the experimental values of Q_{max} and A_{max} found on the six servo systems 0·25 h.p. to 5 h.p.

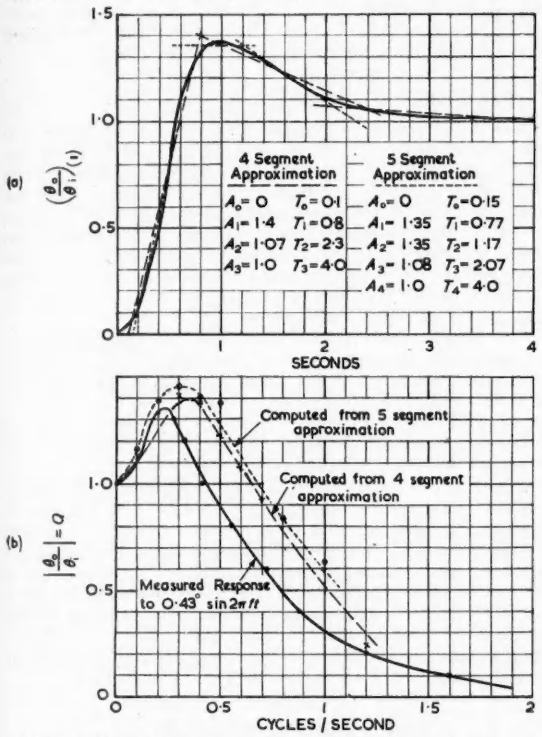


Fig. 19 (a). Measured Response to $1^{\circ}_{(1)}$. (b) Auto follow radar servo

R.M.S.; most of the points lie outside the zone contained between the two empirical curves, although as shown in the earlier Fig. 18 this empirical zone contained a large number of points calculated for linear servo systems.

F_{max}-T_C Relations

Fig. 21(a) records the experimental values of F_{max} and T_C found on the same six servo systems; these points are reasonably near the empirical curve $F_{0\cdot5}=0{\cdot}25/T_C$.

$F_{0\cdot5}$-T_C Relations

Fig. 21(b) records the experimental values of $F_{0\cdot5}$ and T_C found on the same six servo systems; these points are reasonably near the empirical curve $F_{0\cdot5} = 0{\cdot}5/T_C$.

Discussion of Discrepancies

The F_{max}-T_C and $F_{0\cdot5}$-T_C relations show their greatest discrepancies at low values of T_C—say less than 0·2 second;

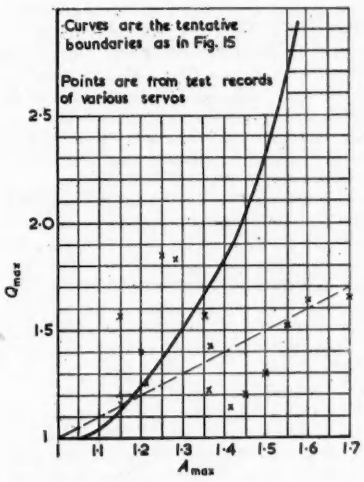


Fig. 20. Experimental Q_{max}-A_{max} relations

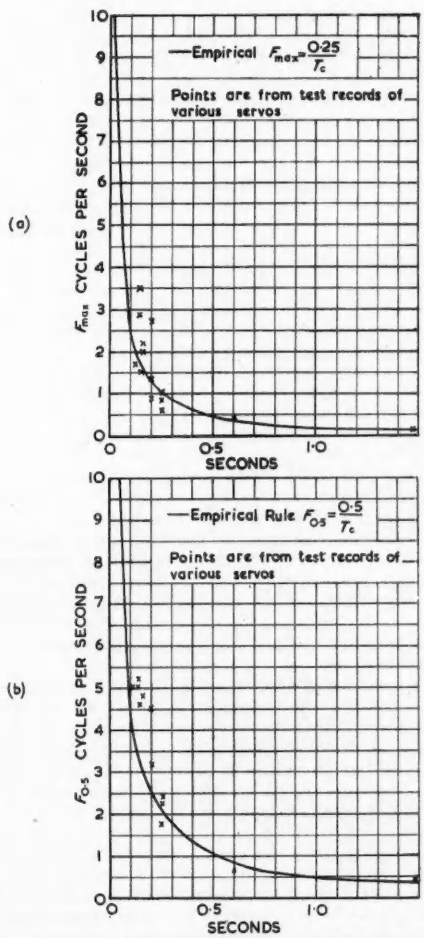


Fig. 21 (a). Experimental frequency at Q_{max}. (b). Experimental frequency at cut-off

T_C = time to first cross correspondence

this would be expected on the following ground:

(a) Systems with $T_C > 0{\cdot}2$ second usually include a stabilizing and/or slugging feedback signal from output acceleration which has the effect of increasing the electro-mechanical time-constant of the servo motor and load by a factor of some hundreds to swamp the prior control delays; such systems do approximate to the simple low pass filters considered in setting up the empirical rules, and may also have improved linearity.

(b) The inherent electro-mechanical time-constant of the servo motor and load is commonly of order 0·2 second, and if $T_C \leqslant 0{\cdot}2$ second has to be achieved, either extreme forcing must be applied to the prior control delays and the linear range correspondingly restricted, or the response contains two oscillatory modes at not very different frequencies; the simple empirical rules relating to F_{max} and $F_{0{\cdot}5}$ can hardly be expected to apply to such two mode systems.

The simple relations $F_{max} = 0{\cdot}25/T_C$ and $F_{0{\cdot}5} = 0{\cdot}5/T_C$ do, however, give a reasonable indication for their intended purpose, and the discrepancies in the Q_{max}-A_{max} relations are of more concern. Mechanical non-linear effects such as backlash and friction account for some of the discrepancies, and in at least one case the tooth ripple errors in the synchro data elements were found to be contributing spurious periodic signals of amplitude comparable to that of the intentional sine wave disturbance. Electrical non-linear effects are also very significant; for example the gain and time-constant of a Ward Leonard generator both decrease as mean excitation level is increased and the resulting harmonic distortion is not revealed by the older test method of observing peak-to-peak movement at the motor shaft; also the reversing excitation during sine wave test does not trace the same magnetic hysteresis loop as the unidirectional excitation used in the step response test.

The only criterion for selecting the test results shown in Figs. 20 and 21 was that both step and frequency responses should have been measured on the same equipment; some of these measurements were taken over seven years ago with rather crude test gear. While modern test gear with Lissajous display would reduce the measuring errors and enable the non-linear responses to be disregarded for the purpose of checking linear theory, the existing test results present a truer picture of the behaviour of practical systems. Linear theory gives valuable guidance, but is no substitute for experience based on actual systems.

Conclusions

Overshoot and undershoot in the response of a servo to input position step are rightly regarded as undesirable because experience has shown that they are associated with resonant amplification of periodic input disturbances within a restricted range of frequencies, and that spurious input signals are likely to occur within this range due to various imperfections of practical equipment and processes. For this reason $A_{max} = 1{\cdot}2$ (i.e. 20 per cent overshoot) or $Q_{max} = 1{\cdot}3$ have been taken as design criteria in past practice.

More recent work on the fundamental "enclosed area" theorems and on the response time scales enforced by practical equipment has shown that some modern specifications of transient crest accuracy during aperiodic input disturbances can be met only if the linear mode response to input position step is shaped to have at least $A_{max} = 1{\cdot}5$ (i.e. 50 per cent overshoot) and probably an appreciable undershoot. Since these step responses are at present synthesized as graphs, the need is felt for a quick method of deriving frequency response direct from a graph so that the final rather tedious breakdown of the graph into Heaviside operational form is carried out only after reaching an acceptable compromise between dynamic error and resonant amplification.

The first stage in filling this need is to combine the best features of existing transformation methods into a new method based on approximating the step response graph by straight line segments. It is shown that for practical servo responses, four segments suffice to give engineering accuracy up to a frequency such that four cycles would occur in the step response settling time; this is well above the conventional "cut-off" frequency $F_{0{\cdot}5}$ at which amplitude response has fallen to half the zero frequency value. The new method shows a useful reduction of computing labour, but it still takes about an hour to transform a typical step response, and the result contains phase-angle information which is superfluous in the particular problem of resonant amplification.

The second stage is therefore to seek for general rules relating Q_{max}, F_{max} and $F_{0{\cdot}5}$, the salient features of the amplitude response to features of the step response such as T_C the time to first cross correspondence, A_{max} the peak value, and the shape of the subsequent recovery to unity. The rules are intended only for immediate guidance while shaping a step response curve either on paper or on an analogue computor and are not put forward as substitutes for the complete transformation or measurement.

The following rules indicate the best that can be expected from a step response having immediate monotonic runback from peak overshoot:

(1) $Q_{max}/A_{max} \simeq 1$ (2) $F_{max} \simeq 0{\cdot}25/T_C$ (3) $F_{0{\cdot}5} \simeq 0{\cdot}5/T_C$

If a dwell period is inserted at peak overshoot prior to the runback slope, or if an undershoot is introduced, the cut-off frequency $F_{0{\cdot}5}$ is little affected, but F_{max} is reduced and Q_{max}/A_{max} is increased—both undesirable effects from the point of view of resonant amplification given to spurious periodic input signals. It appears, however, that $Q_{max}/A_{max} < 1{\cdot}2$ can reasonably be expected from these types of step response whereas a single mode damped sinusoidal response can give $Q_{max}/A_{max} > 1{\cdot}5$ in the region $A_{max} = 1{\cdot}5$ of immediate interest.

The third stage is to check the new transformation method and the approximate rules against all the available test records on actual servo systems to find out how far the predictions from linear theory are borne out in practice. There is fair agreement on resonant and cut-off frequencies, but the recorded values of Q_{max} show a much wider scatter than the predicted zone.

The future programme should be partly the collection of more experimental evidence, but mainly the use of the present approximate rules to guide the synthesis of further standard forms extending the collection originated by Whiteley some seven years ago. These standard forms present the data in the most convenient way for practical use because they reduce the linear mode problems to the solution of simple simultaneous equations and leave the designer free to concentrate on the problems encountered in the actual circuits and in the non-linear region.

Errata

In part 2 the last line of equation (14) should read:

$$= kCR\left(\frac{\omega^2 CR + j\omega}{1 + \cdot\omega^2(CR)^2}\right) \rightarrow Kj\omega \text{ as } CR \rightarrow 0$$

In the index of the exponential in equation (22) D_D should read T_D.

Acknowledgments

The author's thanks are due to his colleague, Mr. J. A. Stokes, for constructive criticisms during the preparation of this article and to the Directors of The British Thomson-Houston Co., Ltd., for permission to publish it.

REFERENCES

12. Whiteley, A. L. Theory of Servo Systems with Particular Reference to Stabilisation. *J. Instn. Elect. Engrs.* 93, Pt. II, 365 (1946).
13. Chestnut, H., Mayer, R. W. Comparison of Steady State and Transient Performance of Servomechanisms. *A.I.E.E. Technical Paper* 49-196 (May, 1949).
14. Gibbs, W. *Nature*, 59, 606 (1899).
15. Guillemin, E. A. Communication Networks, Vol. 2, p. 479 (Wiley, 1935).
16. McColl, L. A. Fundamental Theory of Servomechanisms. p. 37 (Van Nostrand, 1945).

Short News Items

The Radio Industry Council announces the award of premiums of 25 guineas each for articles published in the public technical press during 1953 as follows:—

"Spectrum Equalization" by G. G. Gouriet, A.M.I.E.E.
(*Wireless Engineer*, May, 1953.)

"Triode Transformation Groups" by A. W. Keen, M.I.R.E., A.M.I.E.E.
(*Wireless Engineer*, October, 1953.)

"A Cylindrical Magnetron Ionization Gauge" by A. H. Beck, B.Sc.(Eng.), A.M.I.E.E., and A. D. Brisbane.
(*Vacuum*, April, 1952—published April, 1953.)

"The Scanning Electron Microscope and the Electron-Optical Examination of Surfaces" by D. McMullan, M.A., Ph.D.
(*Electronic Engineering*, February, 1953.)

"A Linear Sweep Cathode-Ray Polarograph" by H. M. Davis, B.Sc., A.R.I.C., and Miss J. E. Seaborn, B.Sc.
(*Electronic Engineering*, August, 1953.)

"Selective Calling for Radio-Telephone Systems" by J. R. Pollard, M.A., A.M.I.E.E., M.I.R.E.
(*Electronic Engineering*, December, 1953.)

The presentation of the awards will take place at a luncheon to be held by the Public Relations Committee of the Radio Industry Council on Thursday, 11 March.

The Mond Nickel Fellowships Committee invites applications for the award of Mond Nickel Fellowships for 1954. The main object of these Fellowships is to enable selected applicants of British nationality and educated to university degree or equivalent standard to obtain additional training and wider experience in industrial establishments at home or abroad, so that they will be better qualified to appreciate the technological significance of research, if they are subsequently employed in executive or administrative positions in the British metallurgical industries. Each Fellowship will occupy one full working year and it is hoped to award five each year of an approximate value of £900 to £1 200 each. Full particulars and forms of application can be obtained from the Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London, S.W.1.

Mr. E. E. Jones, who was for some years in charge of the Telecommunications Division of the British Philips Group of Companies and has been Commercial Manager of Messrs. Savage and Parsons Ltd, Watford, since 1949, is relinquishing his position there to take over the direction of the commercial activities of the Solartron Electronic Group of Companies.

The BBC announces the appointment of Mr. A. I. Bray as Engineer-in-Charge, Television Outside Broadcasts (London), and Mr. H. O. Sampson as Head of Technical Operations Television Studios.

The Council of the Telecommunication Engineering and Manufacturing Association have appointed Mr. H. Faulkner to the office of Director of the Association.

Precision Rubbers Ltd, Bagworth, Leicestershire, announce that Dr. C. M. Blow has joined the Board of the Company as Technical Director. He will be responsible for the research and technical development work of the Company.

Marconi's Wireless Telegraph Co. Ltd, at the request of the Science Museum, have provided a working demonstration spark transmitter and coherer receiver with morse inker, similar in principle to the original apparatus used by Marconi in his early experiments.

Pye Ltd have supplied a camera chain, a telecine camera and vision and sound transmitters for the first television station on the African continent which was set up at Casablanca recently. They have also received an order for three camera chains, together with associated equipment from the Japanese public service broadcasting organization which was established by Government charter in February, 1953.

Solartron Laboratory Instruments Ltd have now changed their address to Solartron Works, Queens Road, Thames Ditton, Surrey. A new factory has been acquired and a considerable expansion programme is under way.

Decca Radar Ltd, announces that it has been awarded a contract by the Ministry of Supply for a number of Decca 424 Airfield Control Radars. These equipments will be used by the RAF to enable jet aircraft to be landed in rapid succession, in poor visibility.

Le Salon National de la Pièce Detachée Radio announce that their annual exhibition of radio parts and components will be held from 12-16 March at the Parc des Expositions, Paris. At the same time as the exhibition there will be a conference on the new techniques and future of the radio and television components industry in France. Further details may be obtained from the offices of Le Salon National de la Pièce Detachée Radio, 23 Rue de Lubeck, Paris.

The Royal Society announce that the first appointments to United States (F.O.A.) Research Fellowships have been made by the National Academy of Sciences Washington, on the nomination of the Royal Society, as follows. Mr. G. N. Lance, employed by Hawker Aircraft Ltd, to work on problems in unsteady supersonic aerodynamics at the University of California under Professor John Miles. Mr. S. H. Parker of University College, Leicester, to carry out research in physical-organic chemistry at the Massachusetts Institute of Technology under Professor Gardner Swain. The Fellowships were instituted last year with funds provided by the United States Government, through its Foreign Operations Administration.

The Regional Advisory Council for Higher Technological Education has prepared, for the sixth year in succession, a summary of the applied research in electrical engineering in progress in university colleges and technical colleges in London and the Home Counties. In issuing this document the Council hopes to stimulate and further the undertaking of applied research. Copies are available from the Regional Advisory Council, Tavistock House South, Tavistock Square, London, W.C.1.

The British Council, in conjunction with the Engineering Department of the British Post Office, is organizing a course in London from 27 June-10 July designed to show how point-to-point radio circuits for the internal and overseas communications of the United Kingdom are planned, equipped and operated. Details may be obtained from the offices of the British Council, 65 Davies Street, London, W.1.

A. H. Hunt (Capacitors) Ltd, of London, have announced the formation of Hunt Capacitors (Canada) Ltd. The new company, with plant and production facilities, located at Ajax, Ontario, will manufacture capacitors previously imported from England for the Canadian electrical and industrial markets.

Multicore Solders Ltd, of Hemel Hempstead, have recently issued a recommended procedure for the soldering of printed circuits. They have been engaged for some time in the preparation of suitable fluxes and other allied materials and are now able to offer a comprehensive scheme which can be used to give successfully soldered circuits with a good cover of solder over all metal parts.

The Bronze Medal of the City and Guilds of London Institute for the best student in Great Britain in the 1953 Intermediate Radio Servicing Examination has been awarded to Mr. J. McCubbin of Glasgow.

Erratum. On page 82 of the February issue in the description of the Oscilloscope Type XT.316, "Radio Research Establishment" should read, "Radar Research Establishment".

BOOK REVIEWS

Vacuum Tube Oscillators

By William A. Edson, 476 pp., 250 figs. Demy 8vo. John Wiley & Sons, Inc., New York. Chapman & Hall Ltd., London. 1953. Price 60s.

THE author states in the preface that this book is intended to serve as a reference work and that the level of the treatment is directed towards the graduate of the usual four year course in electrical engineering.

It would appear that this aim has been reasonably well achieved, although some students may be frustrated by the continual recourse to references, many of which may not be easily available. In many cases important information and relevant discussions are omitted, and the gaps in continuity are intended to be filled from further exploration of a bibliography of 352 references. In this way the author solves the problem of space economy in dealing with a subject which could easily fill many volumes, and it is true to say that although a great deal of very useful material has been provided, the work is by no means a complete treatment of "Vacuum Tube Oscillators."

The book commences with a short introduction to the fundamental principles, properties and types of oscillators. Chapter II reviews the transient behaviour of linear systems and introduces useful ideas (particularly from the mathematical viewpoint) which form the basis of later discussions.

In Chapter III, transitron and dynatron negative resistance oscillators are briefly examined, and methods are given for calculating amplitude and frequency and for calculating the extent to which frequency is modified by the presence of harmonic currents. In Chapter IV, on non-linear oscillations, use is made of isocline diagrams, cyclograms and van der Pol's equation. Many students will find this a very difficult subject, and the presentation is difficult to follow.

Chapter V deals with feedback systems and stability criteria. Nyquist's criterion and plot are rather sketchily explained.

The first five chapters will be of considerable interest to the advanced student and form the theoretical basis for the remaining chapters which are of a more practical nature.

Chapter VI on resonators is extremely useful, and the properties of capacitors and inductors in connexion with oscillators are well explained; quartz crystals are dealt with very briefly.

In Chapters VII, VIII and IX, many linear oscillator circuits are examined, and in Chapter X, several different criteria for the presence or absence of intermittent operation in various types of oscillators are presented. Chapter XI is devoted to the special problems which arise when the power output required is relatively large but the frequency is low enough to be consistent with lumped circuit techniques. The applications discussed are those connected with dielectric and induction heating, diathermy and cyclotrons.

The next and largest chapter (46 pages) provides interesting discussion and analysis of the more familiar and useful relaxation oscillators, including the multivibrator, blocking oscillator and Puckle's saw-tooth generator. Locking and synchronization of oscillators form the subject of Chapter XIII. Several aspects are very helpfully examined, including the synchronization of ordinary harmonic and relaxation oscillators and the use of the locked oscillator as a detector of frequency modulation.

Frequency multiplication and division, tube and thermal noise, amplitude and frequency modulation of oscillators and automatic frequency control are the subjects of four chapters, and finally, Chapter XVIII deals with long line and multiple resonance effects associated with coupled circuits or circuits involving several inductors and capacitors, or lumped elements connected by low-loss electrically long transmission lines. A bibliography, name index and subject index complete the book.

This volume is well written and authoritative, and no important mistakes have been noticed. The author has been able to embody some freshness in his presentation and this is indeed creditable, but in some respects the presentation lacks compactness, and occasionally explanations are not as clear as might be desired, particularly in the first chapters where clarity is particularly important.

At the end of each chapter there are problems designed to stimulate interest and endeavour, and these would be much more valuable if answers to the numerical parts were provided.

It should be understood that this book is designed for advanced students of good mathematical standard, and will be of limited use for beginners and casual readers. Within the framework of the criticisms given, it is a valuable addition to technical literature.

H. V. SIMS.

Principles of Electronics

By L. T. Agger. 340 pp., 100 figs. Demy 8vo. Macmillan & Co. Ltd. 1953. Price 18s.

THIS book lays no claim to prepare the reader for particular examinations, but rather to give an insight into the fundamental principles of electronic devices and their associated circuitry. Knowledge of mathematics and electrical technology to Ordinary National Certificate standard is pre-supposed. An introductory chapter dealing with atomic structure and the electronic theory of conduction is followed by a quantitative treatment of electron dynamics, together with a note on the M.K.S. system. Thermionic emission and conduction through gases lay the foundations for a study of both the vacuum, and the gas-filled diode. Various methods of rectification are then discussed, together with ripple filters; the simple neon stabilizer is also mentioned. The properties of the triode, and its applications as a voltage amplifier are then explained; constructions of dynamic characteristics and of various types of load-line are shown. Tetrodes and pentodes are followed by a description of A.F. amplifiers, frequency distortion, and feedback. Simple tuned amplifiers, Miller effect, and the variable-μ valve (this rather sketchily) are described in the next chapter then power amplification is dealt with. Attention is then turned to the thyratron and some of its applications. After an introduction showing the analogy between various electrical and mechanical properties, a simple electro-mechanical oscillator is described, using coils encircling a bar-magnet suspended on a spring; the conventional types of oscillator circuits then follow in a readily-assimilable manner. The remaining chapters contain treatments of modulation, detection, the C.R.T., and photo-electric circuits. Each chapter concludes with a set of exercises with answers; appended at the end of the book are selected questions set by various examining bodies. Two mathematical appendices are given on the solution of the differential equation of the free oscillatory circuit, and the phase shift and attenuation of a three-mesh C-R network. On page 219, paragraph (i) should be (1), since paragraphs (2) and (3) follow. On page 220, the fifth word

VOLTAGE STABILIZERS

By

F. A. Benson, M.Eng., A.M.I.E.E., M.I.R.E.

(University of Sheffield)

Price 12/6

This monograph describes the various devices employing saturated elements, glow-discharge tube circuits and thermionic valve arrangements for voltage stabilization. A comprehensive bibliography is included.

Order your copy through your bookseller or direct from

Electronic Engineering

28 ESSEX STREET, STRAND, W.C.2

on the fifteenth line should be " damped," instead of " undamped." Due, probably, to a printer's error, the answers to exercise 26 (b) and (c) on page 195 are incorrect. The author has an obvious flair for lucid exposition, using only the minimum of mathematics. The book may be confidently recommended to the venturer into the vast field of electronics, and should be a useful additional text-book for the student.

H. STIBBE.

The Magnetic Amplifier

By J. H. Reyner. 119 pp., 80 figs. Demy 8vo. 2nd Edition. Rockliff Publishing Corporation Ltd. 1953. Price 15s.

THIS is virtually a re-print of the first edition (see *Electronic Engineering*, June, 1951, page 242), with the addition of four recent papers to the group of references which are not specifically mentioned in the text: scrutiny of the contents table and index, and sampling a number of pages of text, failed to reveal the slightest alteration elsewhere. Consequently your reviewer's previous criticism still stands, that series- and parallel-connected transductor arrangements are stated on page 19 to be comparable while it is correctly pointed out on page 46 that the parallel-connected arrangement is likely to have a slower response than the series-connected one. In the light of recent developments, one is now inclined to ask for a clearer distinction between the " bias " and " feedback " functions of " self-excitation," since there is a trend in the literature to use the term " self-excitation " instead of " feedback " when the gain is raised by passing rectified output current through a control winding. None the less, the book is strongly recommended to all who do not possess the first edition, since it is clearly written and gives a reliable introduction to the properties and design of magnetic amplifiers with the minimum of mathematical complication.

D. A. BELL.

Radio Engineering

By E. K. Sandeman. 779 pp., 120 figs. Demy 8vo. Volume 1. 2nd Edition. Chapman & Hall Ltd. 1953. Price 60s.

THIS book is presented as a thoroughly revised edition of the original Volume 1, which appeared in 1947 and has since attained a well-merited measure of popularity as a general text. Minor additions and corrections have been made resulting in a slightly longer volume of 779 pages instead of 775, although space has been saved by the compression of some of the more extravagant illustrations. Due, however, to the use of heavier paper the book is considerably bulkier and perhaps helps to justify the 15s. increase in price.

In its sixteen chapters the book deals thoroughly with the fundamentals of radio engineering (effects and units, sine waves, A.C. theory, resonance and tuning, harmonic analysis, etc.), passes on to valves, amplifiers and oscillators—some 200 pages, and concludes with an exhaustive treatise on transmission and transmitters—300 pages. As formerly, it is a curious blend of an internal instruction and procedure handbook, and a general text. It was written originally as a staff manual for BBC maintenance engineers and this shows all too clearly in some sections where detailed descriptions and operating procedures relating to particular BBC equipments are given; sections which to the general reader have only the doubtful use of illustrating practice instead of theory. The use of terms and descriptions stemming from the author's day-to-day jargon has little to recommend it.

Because of this bias the book is essentially practical in treatment and little touches such as the heavy type reminder " Remember to enter wire radius: not diameter " on Fig. 7/11:13 are typical. Emphasis is predominantly on what might be termed " classical " aspects of radio transmission and the techniques of television and radar are ignored although frequency modulation is treated equally with amplitude modulation in the appropriate sections. This is not to say that the book suffers from this single-mindedness of purpose; it is perhaps in some ways an advantage. Within his chosen terms of reference the author does deal thoroughly with a wealth of topics and does not hesitate to tackle some points conveniently overlooked in other texts—examples being R.F. resistance and the spectra of F.M. signals.

Specific additions are difficult to note but although the book appears unchanged up to page 200 or thereabouts it is clear that minor points have been added. Resetting of the type has also been undertaken with the result that several printer's errors absent in the first edition are present. The use of non-preferred terms such as capacity for capacitance and condenser for capacitor is continued. If the general reader will remember that BBC practice, admirable though it is, is not the only one and that authorities and views—notably American, not represented at all—also exist, the book is a useful revision and will extend the currency already claimed by the first edition.

E. D. HART.

The Year That Made The Day

79 pp., 100 figs. Demy 8vo. The British Broadcasting Corporation. 1953. Price 6s.

THIS book gives a short account of the planning and preparation by the BBC which enabled millions of people to participate in the ceremonies of Coronation day by television and radio. It is well illustrated and contains photographs from the television screen itself.

The Practical Electrician's Pocket Book 1954

Edited by R. C. Norris. 540 pp., 100 figs. Demy 16mo. Odhams Press Ltd. 1953. Price 5s.

THIS edition includes four new chapters on: Electronics, Maintenance of Cookers, Bell, Alarm and Call Systems, and Fans and Ventilation. There are also revisions of several other sections. In all, some sixty-eight sections contribute towards this popular reference book.

CHAPMAN & HALL

JUST PUBLISHED

A Revised Edition of

Sturley's RADIO RECEIVER DESIGN

PART 1:

RADIO FREQUENCY AMPLIFICATION & DETECTION

672 pages Illustrated 56s. net

FIELDS AND WAVES IN MODERN RADIO

by

Simon Ramo

Vice President, Hughes Aircraft Co. Research Associate California Inst. of Tech.

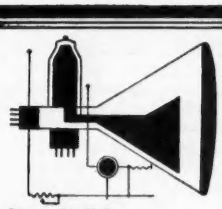
and

John R. Whinnery

Professor of Electrical Engineering University of California

576 pages 266 figures 70s. net

37 ESSEX STREET, LONDON, W.C.2.



Smith's for current "know how"

From Smith's shops and bookstalls you can quickly obtain technical books on the latest developments in circuit design, new components, methods and new theories. Books not actually in stock can usually be supplied within a day or so. Smith's Postal Service can send books to any address at Home or Overseas. Lists of the standard works on any subject supplied upon request.

W. H. Smith & Son

FOR TECHNICAL BOOKS

HEAD OFFICE: STRAND HOUSE, W.C.2

ELECTRONIC EQUIPMENT

A description, compiled from information supplied by the manufacturers, of new components, accessories and test instruments.

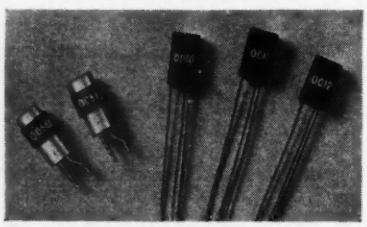
Point-contact and Junction-type Transistors

(Illustrated below)

MULLARD LTD have recently announced the first of a range of point-contact and junction-type transistors for experimental purposes. They are available, in reasonable quantities, to electronic equipment designers wishing to investigate the potentialities of transistors, and to carry out practical experiments in transistor circuits. The range includes two point-contact types, the OC50 and OC51, and three junction types, the OC10, OC11 and OC12.

The OC51 has a better high frequency characteristic and a shorter turn-off time than the OC50. The OC50, however, operates more satisfactorily than the OC51 at the collector "bottomed" condition. In this condition the "fully-on" transistor of extremely low impedance passes a current determined almost entirely by the outside load.

The junction transistors, OC10, OC11



and OC12 are designed for economy in power supplies and, in both amplifier and oscillator circuits, they will operate satisfactorily from H.T. supplies as low as 1·5V, with current consumptions of similar low order. Under suitable conditions they will work with H.T. supplies of only a fraction of a volt.

The OC11 is a general-purpose amplifier which, in a grounded emitter circuit, gives a current amplification factor of 17. Under similar conditions the OC12 gives a current amplification factor of 30, and is intended primarily as an output transistor, although it can, of course, also be used in amplifier circuits. The OC10 is a low-noise version of the OC11 and is intended for use in the early stages of high-gain amplifiers.

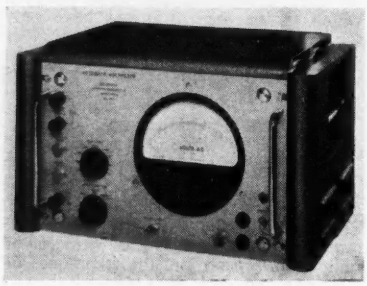
Mullard Ltd,
Century House,
Shaftesbury Avenue,
London, W.C.2.

Feedback Valve-Voltmeter

(Illustrated above right)

IN the model VF.252 valve-voltmeter the changes in the forward to backward impedance ratio of the meter rectifiers has been overcome, resulting in a higher degree of accuracy than has hitherto been obtainable with rectifier type instruments.

A 6in scale meter with a 1mA movement is employed. Nine sensitivity



ranges covering from 15V down to 1·5mV for full-scale indication are provided. On the latter range the scale is calibrated in 20μV steps and useful readings are obtainable down to 30μV. The input impedance is greater than 50MΩ and the accuracy of indication inside $\pm$1 per cent of full scale except on the two highest sensitivity ranges where the impedance is 30MΩ and the accuracy $\pm$2 per cent. An optional 1MΩ 10:1 input attenuator is provided, thereby effectively extending input voltage range up to 150V full scale. In addition, alternative connexions are provided for an isolated input using a wideband 1:1 transformer with a primary inductance of 50H. An output of 3V R.M.S. for full-scale deflexion is brought out to a socket on the front panel and is available for display on an oscilloscope. The signal-to-noise ratio at the output is better than 40db at full-scale.

The instrument covers a frequency range of 10c/s to 100kc/s.

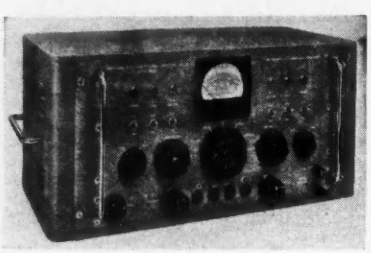
Solartron Laboratory Instruments Ltd,
Solartron Works,
Queens Road,
Thames Ditton, Surrey.

Twin Stabilized Power Supply

(Illustrated below)

THE type PSU1 has two independent stabilized outputs which may be connected separately either as lines positive or negative to earth or in series to provide an extended voltage range or a centre-tapped power supply. Where an accurately centre-tapped variable supply is required the unit can be supplied with a self-balancing connexion.

The output of each stabilizer is variable from 180 to 350V at up to 180mA, a negative supply of 170V at 2mA is also available. A total of 72W heater



power at 4 or 6·3V is also provided.

The output is monitored by a 3½in meter which may also be used for measuring external voltages, the sensitivity being 1 000Ω/V.

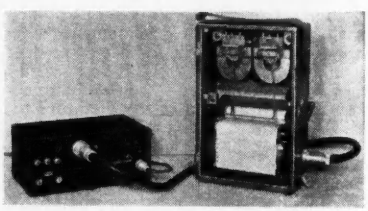
Omicron (Electronics) Ltd,
Hermitage Buildings,
Longfellow Road,
Walsgrave, Coventry.

Duplex Quick Response Recorder

(Illustrated below)

THIS instrument, which is of the continuous roll chart type contains two movements which are essentially D.C. recording voltmeters having a rapid response and negligible pen to paper friction. The maximum torque produced by the pen movement is approximately 7oz in.

The recorder is servo operated and works in conjunction with an amplifier unit, the amplifier and recorder being connected by a 5 ft. long 18 core flexible cable with plug and socket ends.



The input to the recorder is opposed by the feedback voltage from a resetting potentiometer which is controlled by the position of the pen. The error, being the difference between these voltages, is amplified and drives the pen movement until the feedback voltage balances the input.

The pen zero may be set in any position and a solenoid operated time marker pen is also included.

The maximum sensitivity may be set to suit requirements between the limits of $\pm$10 volts to $\pm$4 volts for a deflexion of $\pm$1 7/16 inch. It may be continuously reduced down to zero by means of a potentiometer control on the front panel of the amplifier unit. Provision is made to switch this control out of circuit if desired. The input impedance is approximately 50kΩ with the sensitivity control potentiometer in circuit and approximately 2MΩ with it switched out.

The voltage across the resetting potentiometer is stabilized and the sensitivity is thus independent of mains variations.

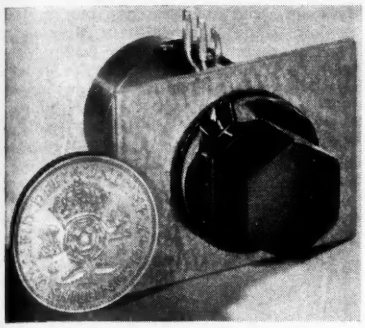
The instrument will record sine wave voltages up to 15c/s with an amplitude error not exceeding 15 per cent for a peak-to-peak amplitude of 1½ inches. At smaller amplitudes the frequency response is proportionally higher.

The synchronous motor driven chart clock has a four-speed (lever selected) gear box providing for chart speeds of ½, 1, 3, or 6 inches per second in the

case of the RD.15 or 2, 4, 12 and 24 inches per minute for the RD.15A.

Recordings can be made either in ink or on teledeltos paper.

Evershed & Vignoles Ltd,
Acton Lane Works,
Chiswick,
London, W.4.



Midget Attenuator

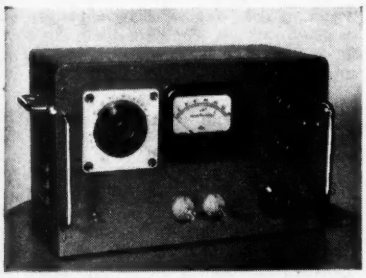
(Illustrated above)

TO meet a demand for a midget stud-type attenuator or fader, Painton & Co. Ltd. have introduced a new midget instrument known as type M.

Primarily designed for audio applications (although in special circumstances it may be satisfactory on carrier frequencies up to 4Mc/s) the unit measures only 1¼in diameter and 1 5/16in long. Painton ¼-watt high stability carbon resistors are employed and the unit can accommodate either a 10-step twin-arm network (e.g. bridged-T) or a 20-step single-arm network (e.g. unbalanced potentiometer).

A special knob and dial have been designed for use with this attenuator, in which full advantage has been taken of the extreme compactness, so that the dial diameter is no greater than that of the unit.

Painton & Co. Ltd,
Kingsthorpe,
Northampton.



Capacitor Power Factor Measurement

(Illustrated above)

A RECENT addition to the range of capacitor power factor measuring instruments manufactured by Viduna Instruments is a model covering the range 150 to 150 pF and giving a direct reading of power factor on a 3½in meter.

There are three ranges of indication 0 to 25, 0 to 100 and 0 to 400×10^{-4} tangent of loss angle at 1Mc/s. A D.C. polarizing voltage can be incorporated for the application of voltages up to 1 000V in steps of 100V.

Other models cover the range of 4 to 1 000pF.

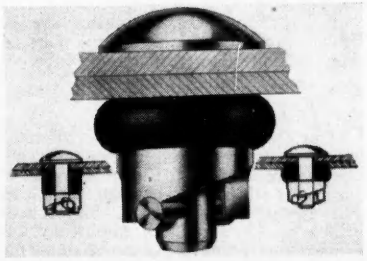
Viduna Instruments,
11 The Ridgeway,
Epsom, Surrey.

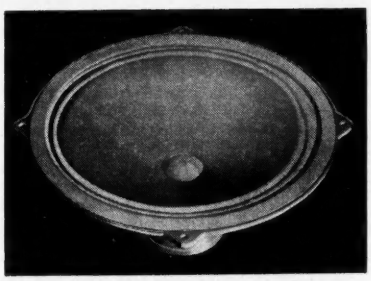
Panel Fasteners

(Illustrated below)

VIBREX fasteners are designed to lock removable panels in position; a typical application being the locking of the panel and chassis into an instrument case. To fit the Vibrex, which depends on the expansion of rubber for its locking action, only two plain holes are needed, one in the removable panel and the other in the base. The action of the fastener can be seen from the illustration.

Silentbloc Ltd,
Victoria Gardens,
London, W.11.





Loudspeakers

(Illustrated above)

THE main feature of the latest range of Stentorian loudspeakers is the cone which is made from uncured cambric and bonded pulp, the whole being cured together into a composite cone by a new manufacturing process.

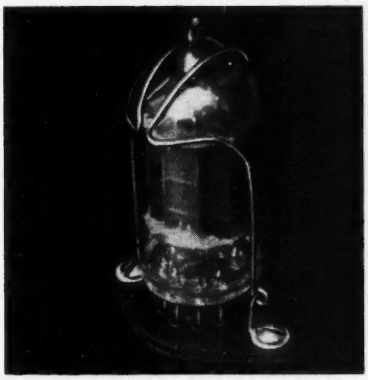
They are available in 6, 8, 9 and 10in sizes; the first two are fitted with 10 000 gauss magnets and the latter two with 12 000 gauss magnets. The 10in unit will handle 10 watts, the frequency range is 30c/s to 14kc/s and the bass resonance 30c/s. All the units are dust proof.

Whiteley Electrical Radio Co. Ltd,
Victoria Street,
Mansfield, Notts.

Valve Retainers and Extracting Tongs

(Retainers illustrated top right)

THE latest addition to the range of Spearette valve retainers is the type W. These are designed for use with miniature valves and, as shown in the illustration are of extremely simple construction.



Also recently introduced by the same firm is a universal valve and screen can extracting and replacement tool. The tongs are capable of handling all types of miniature valves and their associated cans. The grips in contact with the valve are covered with a Neoprene sleeve.

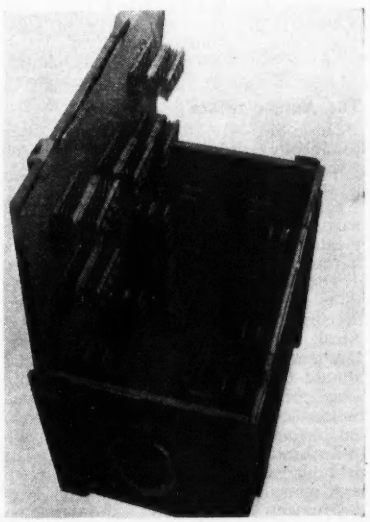
Spear Engineering Co. Ltd,
Titan Works,
Limpsfield Road,
Warlingham, Surrey.

Shock Absorbent Packing

(Illustrated below)

METPAK shock absorbers are designed to protect, while in transit, heavy and delicate equipment such as electronic control apparatus, radar equipment, television receivers, etc. Each Metpak units consists of a number of springs mounted between a pair of metal plates. The units may be used singly, in pairs or as triple units. This method of packing has been approved and is used by the Ministry of Supply. The illustration below shows an outer container with double Metpaks assembled *in situ* ready for the inner case to be fitted.

Brayhead Springs Ltd,
Full View Works,
Kennell Ride,
Ascot, Berkshire.



LETTERS TO THE EDITOR

We do not hold ourselves responsible for the opinions of our correspondents)

The Wurlitzer Organ

DEAR SIR,—With reference to Alan Douglas's article in the November, 1953, issue, I would like to make two points.

The first one, which is of minor importance, is that if the overtones from a sound producer are not integral multiples of the fundamental, then they cannot be called harmonics.

Secondly, Table 1 (b) in the article is entitled "Typical Overtones for a Free Reed." This table applies only to a cantilever clamped rigidly at one end and having a uniform cross-section throughout its length. While a free reed approximates to a rod clamped rigidly at one end, its cross-section is not uniform throughout the length. Therefore the table given could not apply except in special and unusual cases. As the result of personal work, I have found that the tone produced by a free reed approximates to a harmonic series, typical figures obtained being:—

Fundamental	... 40	per cent	f
Octave ...	... 50	per cent	$2f$
Twelfth ...	... 75	per cent	$3f$
Fifteenth ...	... 25	per cent	$4f$
Seventeenth	... 12	per cent	$5f$
Nineteenth	... 100	per cent	$6f$
Twentyfirst	... 15	per cent	$7f$
Twentysecond	... 10	per cent	$8f$

The reed thus tested was completely unresonated and fastened to a small block of wood in lieu of a soundboard. The analysis having been done with a Dawe Audio Frequency Analyzer, the harmonics cannot be attributed to faulty analysis technique. It is of interest to notice the effect of the bar's natural overtone at the Nineteenth. In this case it occurred very near to $6f$, and not the $6{\cdot}267f$ of a uniform bar. In the future good voicing technique may consist in so shaping the reed that the fundamental is accentuated, and the first bar overtone is exactly $6f$.

Yours faithfully,
JOHN E. SCOTT.
Birmingham.

The Author replies:

DEAR SIR,—Referring to your letter commenting on the reed tone analysis given on page 466 of the November, 1953, issue:

Firstly, the table does not denote the partials as harmonics although I have mentioned them in the text since true harmonics are present in many reed tones.

The harmonic content of your reed is quite representative of that kind of reed voicing. In the case of reeds for electrical pick-up it is not in general important that overtones above the fundamental should be in any particular relationship since the object is to extract as much fundamental as possible by using a pick-up having an area great compared with the vibrating length of the partials. The formula given applies to weighted reeds and many such are used in this class of instrument. The overtones shown numerically apply to a free reed of uniform cross-section, mass and elasticity. Many reeds conform to this condition, particularly those used by the Aeolian Company. The formula for an elemental part of such a reed is:—

$$EI\frac{\partial^4 y}{\partial x^4} = -\ddot{m}y \quad \ldots\ldots\ldots\ldots\ldots (1)$$

where E = Young's Modulus
I = moment of inertia
y = displacement of the section from position of rest
x = distance of section from clamped end
m = mass per unit length

But, in the very common case where the reed contour is variable or the material non-uniform, then formula (1) becomes

$$\frac{\partial^2}{\partial x^2}\left[EI\frac{\partial^2 v}{\partial x^2}\right] = -\ddot{m}y \quad \ldots\ldots\ldots (2)$$

This can only be solved by an approximate numerical method[1] if I, m and probably E are unspecified functions of x. It is a reed of this type which Mr. Scott has analysed, the harmonic content of which has been adjusted empirically. It is clear that whatever harmonic series the reed itself produces, it would be intolerable to simultaneously convert all of these into electrical energy, and the statement on page 469, "careful selection and control of the reeds" is meant to embrace not only the electrical methods adopted to provide the desirable response but also the shape of the vibrating tongue itself.

However, the following additional second order effects greatly influence the final form of the reed vibrations. No reed maintains its physical properties constant throughout its life. Moreover, the ratio of width to length, the aperture between the tongue and the base which determines the rate of shear of the air, introduce complex effects. A thin reed may be set into vibration in another plane due to flexing laterally as the pressure changes. The acceleration at the edges tends to be greater than at the centre due to the rapid increase in wind velocity as the aperture decreases, and this may superimpose further discordant frequencies on the main tone. The building up of a dust film on the edges of the tongue owing to the violent acceleration of air through the slot eventually modifies the generated partials. So does the onset of fatigue in the metal. The damping introduced by mounting in an approximately tuned enclosure affects the overtones audibly. The extent of flexure of the reed tongue with varying wind pressures has a similar effect, and this is partially modified by back pressure in the cavity-pallet system.

The back pressure in the Wurlitzer instrument is controlled by the adjustable mutes as described, and as stated at the end of the article, every single reed is specially contoured and aged in order to reduce inharmonic tones and at the same time have the requisite physical properties for rapid cessation of oscillation. In practice reed tongues vary from approximately 10in × 1·1/4in × 3/32in to 1/4in × 1/40in × ·004in tapering to ·0015in and so far as I am aware, no really comprehensive general analysis has been made for this type of reed dissociated from an air column and resonator; presumably because there has been no demand for such an investigation and the results could not economically be made use of. Mr. H. W. Homer, Mr. D. M. A. Mercer and the Rev. N. Bonavia-Hunt have, of course, examined the properties of the reed organ pipe fairly thoroughly.

The pipe organ reed is quite different since it is unable to pass freely through the slot but strikes it violently since the tongue is larger than the opening. Such a reed is unsuitable for electrical pick-up.

Yours faithfully,
ALAN DOUGLAS.
Radcliffe-on-Trent,
Notts.

REFERENCE

1. TIMOSHENKO, S. Vibration Problems in Engineering. 2nd edition. (Constable & Co. Ltd., 1937.)

Amplified-torque Clutch

DEAR SIR,—Having had requests for further information relating to the Amplified-torque Clutch, described in your issue of January, 1954, I send you the following characteristics of an experimental version of the clutch.

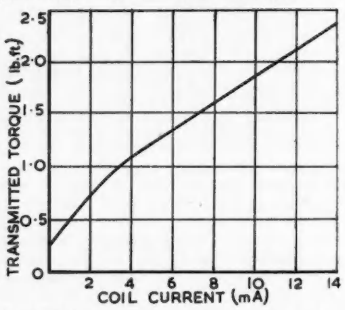


Fig. 1. Relation between output torque and coil current

The magnet has a diameter of 1¼in and its length, including the armature, is 1½in while a brass shim, 0·007in thick, lies between them. The relation between the attractive force on the armature and the coil current, over the linear region, is 0·5lb/mA. The cylindrical surface of the magnet is covered with a brake material and this, together with three turns of steel tape, forms the amplifier. With a slip speed of 12R.P.M. the relation between the output torque and coil current is as shown in the Fig. 1, the slope of the linear region being 120lb.ft/A; a slight fluctuation of less than 0·1lb.ft was observed when making this measurement of the output torque. It will be seen that some torque is transmitted for zero coil current. When pairs of clutches are used in a servo system, these remanent torques tend to cancel and produce a continuous characteristic.

Yours faithfully,
R. VOLES,
E.M.I. Engineering Development Ltd.

An Alternating Current Stabilizer

DEAR SIR,—In the article by P. A. V. Thomas in the December, 1953 issue, the circuit of Fig. 2 presents a number of rather bewildering design features. It would be interesting if the author would explain the following seeming anomalies.

(1) If the H.T. line is at approximately 315 volts (the normal voltage across three 105/30 stabilizers) and if the operating current of the control diode V_1 is only 15μA (as indicated in Fig. 3), the anode potential of V_1 should be about 165 volts in the absence of grid current in the first section of V_2. In fact, however, the absence of such grid current under the conditions indicated, would appear quite impossible. A probable value would be from 12 to 16μA in which case the control voltage would depend almost as much on the grid current characteristics of V_2 as on the emission-temperature characteristic of the control diode V_1.

(2) With a 47Ω cathode resistor in V_2 and the second grid taken to H.T. negative, the anode current in the second section of this value is not likely to exceed 100μA or so. Heavy grid current must therefore flow in the second section of V_2 or its grid potential would rise to about 300 volts positive.

(3) Control of V_1 heater voltage by means of a variable resistor in the primary of its heater transformer seems a strange method calculated to distort the secondary voltage waveform and probably to increase the frequency dependence of the output.

It would be interesting to know how stable the output of the stabilizer remains over long periods and how sensitive it is to replacement of V_2 and V_3.

Yours faithfully,
R. C. ROBBINS,
Bedford.

DEAR SIR,—I was interested in the A.C. stabilizer described by Mr. P. A. V. Thomas[1]. I should like to point out that this type of stabilizer gives an excessive output-voltage in the event of diode-failure or certain other types of fault, such as inter-electrode short-circuits in the amplifying valves. Clearly some form of protection is desirable as a maintained overvoltage may well burn out all the valve heaters supplied by the stabilizer.

The requirement for complete protection is simply that the D.C. winding of the saturable-reactor be dis-connected should there be overvoltage at the output. One way of doing this is to use a Mazda 29C1 saturated diode and a relay. The diode filament is run via a 3·5Ω series resistance from one of the 6·3V windings on the transformer T_3 (see Fig. 2, Ref. 1). At the correct A.C. output voltage the diode takes a saturation current of 0·5mA while for a 10 per cent overvoltage the saturation current increases by nearly four times to 1.9mA. This current change is adequate to operate a 20Ω type 3 000 relay. A suitable H.T. for the diode is about 100V which may be derived from 315V line by two resistors. The relay has two pairs of contacts; one pair disconnects the saturable-reactor control-winding and the other pair earths the diode anode so that the relay remains in the held condition.

Perhaps I should also point out that the curve and working point given in Fig. 3 are in error. Firstly the diode emission is shown going up to 35μA although there is a 10MΩ load and a 250V supply (25μA max) and secondly the working point of 16μA implies a diode anode voltage of 155V in the stabilizer. An anode voltage of this magnitude, with negligible space charge, would result in the rapid destruction of the oxide-coated filament. However, from the circuit of Fig. 3 it is apparent that the anode potential is only a few volts (less than the grid-base of V_2) giving an emission of about 30μA. A miniature valve run as a saturated diode under these conditions should be quite satisfactory.

Yours faithfully,
V. H. ATTREE,
Fluid Motion Laboratory,
University of Manchester.

REFERENCES

1. THOMAS, P. A. V. An Alternating Current Stabilizer for Supplying Valve Heaters. *Elect. Engng.* 25, 522 (1953).

The Author replies:

DEAR SIR,—I would like to thank Mr. R. C. Robbins for his comments and with reference to his point (1), I agree that the total current through the 10MΩ resistor in Fig. 2 must be of the order of 30μA and that therefore the operating point (Fig. 3) must be at about V_b = 0·45V and not as indicated (0·35V) though this would be the optimum point; as explained in the text of my article, originally the grid of the second half of V_2 was taken to a positive supply but the stabilizer was found to operate better with almost zero voltage on this grid and from Fig. 3 it will be seen that there is not a great difference in sensitivity between 0·35V and 0·45V. Unfortunately I am no longer at the Royal Technical College, Glasgow, and cannot therefore check the actual operating point.

As regards Mr. Robbins' second point, I agree that grid current will flow in V_3 due to the high anode potentials of V_2; this point had unfortunately been overlooked in the past and is obviously undesirable. As the amplifier must be D.C. coupled, one of two methods might be conveniently used. (a) To tie the anode load of V_2 to a lower D.C. potential, easily obtained from the neon chain, or (b) to couple between V_2 and V_3 using low current neons to drop the D.C. voltage on the latter grids. Of the two methods, (a) would probably be the more satisfactory.

As regards his third point, the method used is simple and the distortion introduced is not likely to be very serious as the secondary load resistance (the valve heater) is small and the distortion introduced can be shown to be approximately proportional to the parallel effect of the source, transformer primary and load impedances which in this case will approximate to the load impedance, though I agree that if the input impedance is reduced then the distortion will also be reduced. As an alternative to the method shown one could use one of the following methods:

(a) A series resistor in the secondary circuit instead of the primary but its value would probably be awkward for a variable resistor.

(b) small continuously variable auto transformer.

(c) No variable component, accepting the output voltage obtained—still of course stabilized.

With regard to the question of stability, I can only state that over a period of several months' operation no change in output was observed and, as stated above, having left the College I unfortunately cannot check the effect of changing V_2 and V_3 but I should imagine that, as is quite common in D.C. amplifiers (of which this is one), resistor R would have to be altered to reset the output to the original value due to differences in the valve characteristics.

In reply to Mr. Attree, I agree that some form of protection is desirable if the stabilizer is to be used in some permanent equipment, however in an experimental set-up as the particular stabilizer was used this is not so important as one is continually taking readings and any sudden change would undoubtedly give extraordinary results and the stabilizer is quickly checked by observation of the meter M, and generally speaking the output voltage would not rise to too high a level. It should be pointed out, however, that the particular faults mentioned are unlikely and using another valve as a safety device, as suggested, does not seem to be the answer but rather some other form of protector such as a maximum voltage voltmeter in which the meter pointer can close a contact at a suitable preset value, say 10 per cent high.

As regards his second point, upon checking my original laboratory notes I find that in Fig. 3 the supply voltage should have been 350V and not 250V as shown and in connexion with the operating point I would ask him to consult my reply to Mr. R. C. Robbins.

Yours faithfully,
P. A. V. THOMAS,
London. S.W.7.

Characteristics of Mazda Diode 29C1

DEAR SIR,—With reference to the article on the Characteristics of The Temperature—Limited Diode Type 29C1 by Messrs. Benson and Seaman which appeared in the November, 1953, issue, there are a number of points that the writer would like to comment upon and also to add information that may be of interest to users.

These comments are based upon work carried out since 1945 in the Engineering Departments of the Edison Swan Company during the development and production of this valve.

The following are selected points from this work:

(a) The 29C1 valve was designed initially for a specific application and like all valve design was a compromise. It is probably now used for a variety of purposes and requirements for which it is not the most suitable design, or type of valve.

(b) As regards initial characteristics, these are a compromise between economic production and uniformity of performance, and the authors' figure of 15 per cent is reasonable. In order to get the close characteristics required it is necessary to mount and weld accurately to length, a very fine piece of tungsten wire. This tungsten wire itself must be maintained to an accurate diameter and this can only be achieved by careful selection from spools of wire of the same nominal diameter but varying by less than ± 0·0002in.

(c) All valves are aged for 48 hours before being shipped out of the factory.

(d) For our standard life test conditions we use an A.C. stabilized power supply for the filament, which keeps the potential within 2 per cent of the nominal value. The anode is fed with 100V from a generator via a safety lamp. Periodic testing is carried out on separate D.C. test boards.

It should be realized that our object is merely to check the quality of the factory product and hence our life test and testing conditions may not be held so academically accurate as those of the authors', or Mr. Attree. Within the limits shown above we have obtained results that are substantially the same as the authors except that ours have gone on until failure of one filament.

(e) To obtain a better life performance we agree that it would be necessary to run with a lower temperature filament, i.e., lower I_s being taken. Alternatively a higher filament wattage valve which may mean a larger bulb would be required. Such an alternative would slow up the rate of response to change of V_f which was an important point in the initial design requirements. The life if run at 4·5V would be seriously reduced, whereas at 3·5V the life would be greatly increased. Over this range the life factor could be of the order of 20 or so, but the total change of I_s would remain approximately the same.

(f) The rate of response for small filament voltage changes is of the order of 0·5 seconds.

(g) We are aware that the valve has a margin of safety for anode voltage rating but as the valve is a commercial type the ratings must always be conservative and hence we do not recommend exceeding our published figures. As we acquire sufficient indication of reliability then our ratings will be changed.

(h) Referring to short term stability, over a period of 8 hours continuous running, sample valves have shown less than 1 per cent variation of anode current with constant V_f. Switching off at night and on again in the morning for a total working period of 20 hours, the stability has been of the order of 2 per cent.

Yours faithfully,
D. L. HALL,
Edison Swan Electric Company, Ltd.
Brimsdown.

MEETINGS THIS MONTH

THE BRITISH INSTITUTION OF RADIO ENGINEERS

Date: March 31. Time: 6.30 p.m.
Held at: The London School of Hygiene and Tropical Medicine, Gower Street, London, W.C.1.
Lecture: Radio Astronomy.
By: R. Hanbury Brown.

North-Western Section

Date: March 11. Time: 7 p.m.
Held at: The College of Technology, Manchester.
Lecture: Colour Television.
By: G. B. Townsend.

West-Midlands Section

Date: March 23. Time: 7.15 p.m.
Held at: The Wolverhampton and Staffordshire Technical College, Wulfruna Street, Wolverhampton.
Lecture: Industrial Application of Electronic Instruments.
By: A. G. Wray.

THE INSTITUTION OF ELECTRICAL ENGINEERS

All London meetings, unless otherwise stated, will be held at The Institution, commencing at 5.30 p.m.

Ordinary Meeting

Date: March 4.
Lectures: Submerged Telephone Repeaters for Shallow Water.
By: R. J. Halsey and F. C. Wright.
The Netherlands-Denmark Submerged Repeater System.
By: A. H. Roche and F. O. Roe.
British Post Office Standard Submerged Repeater Sytem for Shallow-Water Cables, with special mention of the England-Netherlands System.
By: D. C. Walker and J. F. P. Thomas.

Informal Meeting

Date: March 8.
Discussion: How Can Electrical Methods Enhance Industrial Productivity?
Opened by: Sir Henry Clay.

Measurements Section

Date: March 2.
Lecture: Current and Power Relationships in the Measurement of Iron Losses in a Three-Limbed Transformer Core.
By: F. Brailsford.
and: An Automatic Plotter for Magnetic Hysteresis Loops.
By: H. McG. Ross.
Date: March 16.
Lecture: The Minimum-Moment-of-Error-Squared Criterion: a New Performance Criterion for Servo Mechanisms.
and: The Behaviour of a Remote Position Control Servo Mechanism with Hard-Spring Non-Linear Characteristics.
By: J. C. West and P. N. Nikiforuk.

Radio Section

Date. March 10.
Lecture: A Study of some of the Properties of Matter affecting Valve Reliability.
By: E. A. O'Donnell Roberts.
Date: March 22.
Lecture: Colour Television.
By: C. J. Hirsch.

Supply Section

Date: March 24.
Lecture: Cathode-Spot Performance Phases and Control of Mass Transfer in Vapour-Discharge Devices.
By: H. von Bertele.

Cambridge Radio Group

Date: March 9. Time: 8.15 p.m.
Held at: The Cavendish Laboratory, Cambridge.
Paper on Computing Machines.

Mersey and North Wales Centre

Date: March 25. Time: 6.45 p.m.
Held at: The Philharmonic Hall, Liverpool.
Faraday Lecture: Electro-Heat and Prosperity.
By: O. W. Humphreys.

North-Eastern Radio and Measurements Group

Date: March 15. Time: 6.15 p.m.
Held at: King's College, Newcastle-upon-Tyne.
Lecture: A Study of some of the Properties of Matter Affecting Valve Reliability.
By: E. A. O'Donnell Roberts.

North Midland Centre

Date: March 23. Time: 6.30 p.m.
Held at: Bradford Technical College.
Discussion: High Voltage in Theory and Practice.
Opened by: A. R. Rumfitt.

North-Western Centre

Date: March 2. Time: 6.15 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: A Short Modern Review of Fundamental Electromagnetic Theory.
By: P. Hammond.
Date: March 23. Time: 7.30 p.m.
Faraday Lecture: Electro-Heat and Prosperity.
Held at: The Free Trade Hall, Manchester.
By: O. W. Humphreys.

North-Western Radio Group

Date: March 17. Time: 6.30 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: Distributed Amplifiers.
By: W. S. Percival.

North Lancashire Sub-Centre

Date: March 10. Time: 7.15 p.m.
Held at: The North Western Electricity Board, Demonstration Theatre, North Road, Lancaster.
Lecture: Some Aspects of the Design of V.H.F. Mobile Radio Systems.
By: E. P. Fairbairn.

South Midland Radio Group

Date: March 22. Time: 6 p.m.
Held at: The James Watt Memorial Institute, Great Charles Street, Birmingham.
Repeat of North Lancashire Sub-Centre meeting.

Rugby Sub-Centre

Date: March 3. Time: 6.30 p.m.
Held at: The Rugby College of Technology and Arts.
Lecture: Transformer-Analogue Network Analysers.
By: M. W. Humphrey Davies and G. R. Slemon.

Southern Centre

Date: March 3. Time: 6.30 p.m.
Held at: The SEEB Headquarters, Hove.
Lecture: Technical Arrangements for the Sound and Television Broadcasts of the Coronation Ceremonies on June 2, 1953.
By: W. S. Procter, M. J. L. Pulling and F. Williams.

Western Centre

Date: March 8. Time: 6 p.m.
Held at: The South Western Electricity Board Offices, Colston Avenue, Bristol.
Lecture: Telemetering for System Operation.
By: R. H. Dunn and C. H. Chambers.

South-Western Sub-Centre

Date: March 10. Time: 3 p.m.
Held at: The Rougement Hotel, Exeter.
Lecture: Colour Television: Some Subjective and Objective Aspects of Colour Rendering.
By: G. T. Winch.

Norwich District

Date: March 15. Time: 7.30 p.m.
Held at: The Royal Hotel, Norwich.
Lecture: Modern Developments in Atomic Energy.
By: T. E. Allibone.

Oxford District

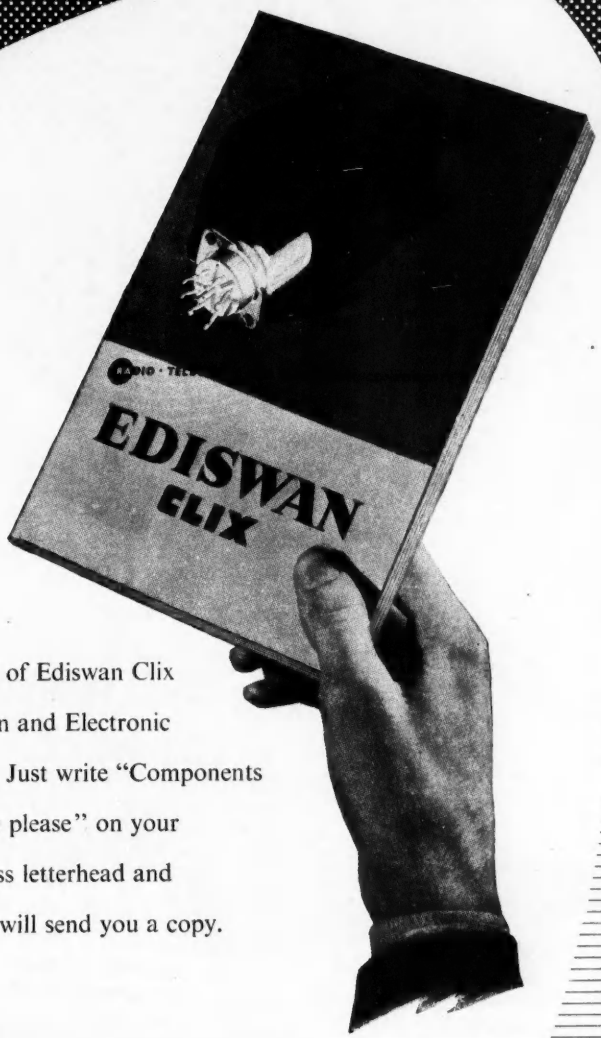
Date: March 17. Time: 7 p.m.
Held at: The Southern Electricity Board, 37 George Street, Oxford.
Lecture: Modern Trends in Television.
By: G. G. Gouriet.

THE TELEVISION SOCIETY

Date: March 12. Time: 7 p.m.
Held at: The Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, London, W.C.2.
Lecture: Trick Effects in Television Production.
By: D. R. Campbell.

Leicester Centre

Date: March 29. Time: 7 p.m.
Held at: The College of Art and Technology, The Newarkes, Leicester.
Lecture: Transistors and other Crystal Valves.
By: D. D. Jones.



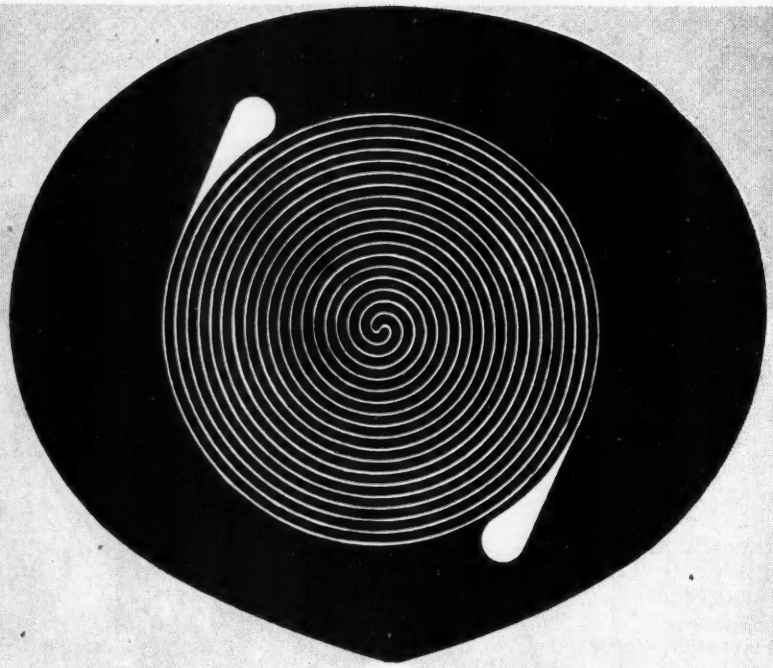
MANUFACTURERS OF EQUIPMENT, and DEVELOPMENT GROUPS are invited to send today for this NEW complete catalogue of Ediswan Clix Radio, Television and Electronic Components. Just write "Components Catalogue please" on your business letterhead and we will send you a copy.

EDISWAN

CLIX

RADIO COMPONENTS

THE EDISON SWAN ELECTRIC COMPANY LIMITED, *Member of the A.E.I. Group of Companies*
155 Charing Cross Road, London, W.C.2 and Branches. *Telephone: Gerrard 8660. Telegrams: Ediswan, Westcent, London.*
C.R.1a Radio Components Sales Office: 21 Bruton Street, London, W.1 *Telephone: Mayfair 5543*



The Saunders-Roe/Technograph Diaphragm Gauge

British and foreign patents pending

An elegant device for the solution of many problems of pneumatic or hydraulic pressure measurement. This strain gauge, of double spiral pattern, is applied to a diaphragm subjected to the pressure under investigation, and an electrical output/pressure calibration curve is taken. By integrating the circumferential strains over the diaphragm area, the double spiral pattern makes the most efficient use of gauge material and strain response of the diaphragm. The double spiral pattern does not sacrifice any of the advantages of the normal foil strain gauge.

Available for immediate delivery

Effective gauge diameters : ¾" and 1". Material : Cu/Ni foil, Araldite lacquer backing. Resistance : 110 ohms central. Supplied in matched pairs to 0.5% resistance values.

SAUNDERS-ROE LTD.

(ELECTRONICS DIVISION) OSBORNE · EAST COWES · ISLE OF WIGHT

There's 1 way 2 store resistors to prevent X asperation

The LAB TESTED CONTINUOUS STORAGE UNIT

THE LABpak Continuous Storage Unit has the maximum points in its favour when it comes to storing resistors. The permutations of the number of preferred values, ratings and tolerances amount to 870, yet the element of chance in selecting the desired resistor is eliminated by the LABpak.

The correct choice is a matter of seconds and certainty, for the resistors are carded in ohmic values etc., and selected with card index simplicity. Empty cards are merely replaced from stock.

This ingenious, foolproof, time-saving continuous storage unit is FREE with the initial purchase of 180 type "R" or 240 type "T" resistors of your chosen values. It will pay you dividends.

BRITISH PATENT No. 680632

RESISTOR SPECIFICATION

Ref.	Type	Loading	Max. Volts	Range	Dimensions
T	⅛-watt	½-watt	250	10 ohms	⅜" × 1/16"
R	⅛-watt	1-watt	500	to 10 megohms	⅝" × ¼"

Tolerance available ±20%, ±10%, ±5%

The Lab Continuous Storage Units are available from your normal source of supply, but more detailed information can be obtained on request.

THE RADIO RESISTOR COMPANY LTD.

50 ABBEY GARDENS, LONDON, N.W.8 · Telephone: Maida Vale 5522

PYE TV for Industry–

At a fire-fighting demonstration in Glasgow

Pye Industrial television was recently used as a method of control in a full scale fire-fighting exercise of the Glasgow Fire Brigade. TV Cameras at the scene of the fire relayed pictures to the Central Headquarters, giving immediate and accurate visual information of the size, condition and progress of the fire.

Observers were enthusiastic regarding the value of television as a new aid to fire fighting. It is not envisaged that local operations would be directly controlled from headquarters, but television removes the difficulties of assessing from verbal reports the size and menace of a particular fire.

This application of television as an aid to Fire-Fighting is only one of the many uses for industrial television. For further information will you please write to Pye Limited, Industrial Television Division, Cambridge.

In basic form the equipment comprises a lightweight television camera and a viewing monitor; these are linked together by a single co-axial cable which may be any convenient length from a few feet to a thousand feet, depending upon the user's requirements.

The camera, weighing only 31 lbs. and measuring 16 x 6 x 14 inches approximately, carries three lenses giving a wide choice of viewing angles and features a newly developed low-cost camera "pick-up" tube possessing adequate sensitivity to normal industrial lighting. In practical terms, a clearly defined picture will be obtained with a scene brightness as low as 50 foot-lamberts—corresponding to the light reflected from an "average" subject placed 4 feet from a 200 watt lamp in a suitable reflector.

The viewing monitor displays a well-defined picture on a 14 inch diagonal rectangular cathode-ray tube with a built-in "black screen" to permit clear viewing with normal room lighting. A normal domestic television receiver may, without modification, be employed as an additional monitor if required.

Alternative versions of the camera and monitor provide scanning standards of either 405 lines or 525/625 lines and the equipment will operate on any normal AC supply voltage, with a total power consumption of only 350 Watts.

PYE LIMITED · CAMBRIDGE · ENGLAND

dag DISPERSIONS

REGD. TRADE MARK

and the modern use of

COLLOIDAL GRAPHITE

In the early days of this century the Acheson Organisation pioneered the development and manufacture of Colloidal Graphite. Today they are the world's largest producers of Colloidal Graphite and other dispersions, and **'dag'** Colloidal Graphite is used in nearly every branch of industry where the heat-resisting, chemically inert and electrically conducting properties of a graphite film are required. Thus, with technical representatives in Britain and in all important industrial countries abroad, this organisation has become a World information centre for those interested in the latest applications of colloidal dispersions to industrial needs. New dispersions and new applications are constantly being developed. Many world-famous firms rely on Acheson for technical co-operation and information, which is freely available. You have only to write and Acheson Colloids will be very pleased to put you, too, on their mailing list to receive news of these important technical developments regularly, as issued.

Aquadag *(Regd. Trade Mark)* **colloidal graphite in water,**

Oildag *(Regd. Trade Mark)* **colloidal graphite in oil,**

Prodag *(Regd. Trade Mark)* **semi-colloidal graphite in water,**

and many other **'dag'** *dispersions of* **GRAPHITE, Molybdenum disulphide,** *glass, silver, Titanium dioxide etc., etc., in water, oil and volatile solvents are used for :—*

High-temperature lubrication • Metal-forming • Engine and machinery assembly and running-in • Parting • Wire-drawing • Impregnation • Various applications in the field of electronics, etc., etc.

Besides supplying the widest range of industrial dispersions, Acheson Colloids are well equipped to make dispersions in various media to customers' special requirements. Write today for full technical information, available free from

ACHESON COLLOIDS LIMITED
18, PALL MALL, LONDON, S.W.1.
Telephone: WHitehall 2034-7 Telegrams: OILDAG, PICCY, LONDON
Also ACHESON COLLOIDS COMPANY, Port Huron, Michigan, U.S.A.

ACHESON
A UNIT OF ACHESON INDUSTRIES INC.

TAS/AC·49

SEALED

against all conditions!

We supply manufacturers of electronic equipment throughout the world, but, whatever atmospheric conditions our spools of fine gauge nickel-chrome resistance wire are subjected to before use, their air-tight plastic containers provide the complete protection against deterioration.

This special packing is but one of the precautions we take to "balance" perfectly the properties of consistency, durability and precision in Cromaloy V.

Cromaloy V

80/20%

NICKEL-CHROME RESISTANCE WIRE

dm AS 20

The **smallest precision soldering instrument** *you've ever seen!*

(ACTUAL SIZE)

- No fatigue . . . as light and easy to use as a pencil (½ oz.).
- Speeds production . . . heats up in 30 seconds.
- Safety first . . . for 6, 12 or 24 volts.
- Prevents damage . . . pin-point heat concentration for small assemblies.
- Robust construction . . . no ceramic or mica formers to break or flake.
- Fully reliable . . . in constant demand by the world's most famous manufacturers.
- 4 MODELS, designed for production line assemblies from hairspring to radio chassis capacity.

Model	*Wattage*	*Bit-size*	*Voltage*
12	12	$\frac{3}{16}$″	6, 12, 24 or 50
9	8.3	$\frac{5}{32}$″	6, 12 or 24
6A	6	$\frac{3}{32}$″	6
6	6	$\frac{1}{16}$″	6

ORYX

MINIATURE SOLDERING INSTRUMENTS

Sole Distributors:

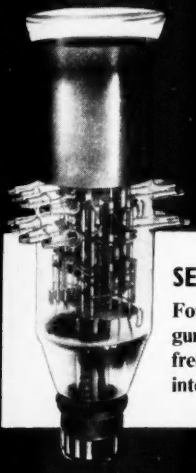
ANTEX · 3 Tower Hill · London · E.C.3

Telephone ROYal 4439

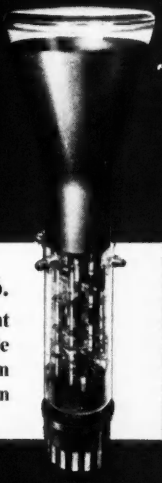
20th CEN

Precision Cathode Ray Tubes

20th Century offer a range of exceptionally fine instrument tubes built by craftsmen. Their performance is unrivalled throughout the world.

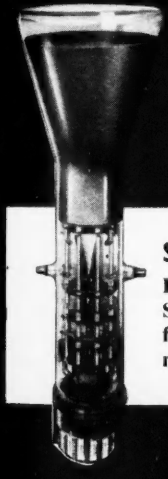


SERIES Q.6.
Four independent guns with complete freedom from intermodulation

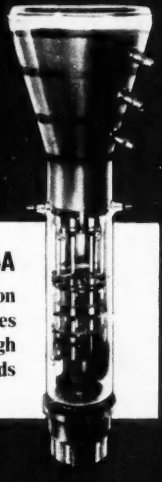


SERIES D.4 & D.6.
Two independent guns with complete freedom from intermodulation

MANUFACTURERS OF MULTIGUN CATHODE RAY TUBES AND GEIGER COUNTER TUBES



SERIES S.4 & S.6.
Precision Single Gun Tubes for high accuracy measurements



SERIES S.6A
Precision Single Gun Tubes for use at high writing speeds

Write for Brochure KT. 301

20th Century Electronics Limited

20th CENTURY ELECTRONICS LTD., DUNBAR WORKS, DUNBAR ST., WEST NORWOOD, LONDON, S.E.27

TELEPHONE : GIPsy Hill 2277/8

THESE ARE OUR PRODUCTS

No.2 special cold forgings

Ceaselessly maintaining, and ever striving to raise even *their* standards of quality and service, and constantly keeping abreast of new trends, Linread have always been most actively concerned with the development of Cold Forging. By retaining the grain flow, Cold Forging increases the strength of the finished product and cuts production costs by showing a raw material saving of up to 70%. And today's toolmaking methods result in a degree of accuracy once considered impossible by this process. Apart from a standard range of precision-made parts, Linread specialists are accustomed to co-operating with manufacturers at the outset to produce special cold forgings to their individual requirements.

Linread

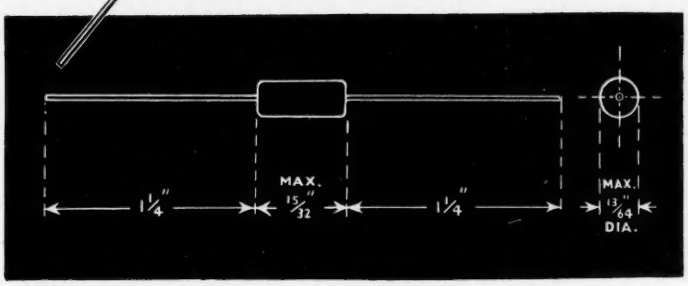
LINREAD LTD · COX ST · BIRMINGHAM

PAINTON

By Appointment to the Profession Engineer

MIDGET R.F. CHOKES

The Painton high 'Q' self-resonant Chokes are precision wound on ceramic formers, protected by a high electrical grade low bake enamel, which ensures absolute constancy of the electrical characteristics.



Although the characteristics of the standard units listed in the Table are primarily applicable to general Television, Communications and Radar designs, Chokes can be manufactured to customers' specific circuit requirements. For Chokes of lower self-resonant frequencies (16 to 45 Mcs./sec.), slightly larger formers are employed.

TYPE	200154	200150	200151
SELF RESONANT FREQUENCY	Mc./sec. 50	Mc./sec. 90	Mc./sec. 180
D.C. RESISTANCE	9 ohms	7 ohms	0.5 ohms
"Q" AT SELF-RESONANT FREQUENCY	60	70	80
INDUCTANCE	30μH	17·5μH	2·95μH

PAINTON

Northampton England

ATTENUATORS AND FADERS • STUD SWITCHES • FIXED AND ADJUSTABLE WIREWOUND RESISTORS WIREWOUND POTENTIOMETERS • MIDGET R.F. CHOKES • HIGH STABILITY CARBON RESISTORS • TERMINALS PLUGS AND SOCKETS • KNOBS, DIALS AND POINTERS • TOGGLE SWITCHES • PUSH BUTTON SWITCHES

Fans you can trust

Dare you risk failure in valve cooling?
Then remember that *Aerofoil* fans offer electronic engineers the same reliability that has made them the choice for mines, ships and numerous industrial applications.
After all, it takes long experience and large resources to make fans and their motors that are completely dependable.
Hence *Aerofoil* fans are used everywhere by engineers who play safe. Services specifications can be fulfilled.
Ask to see samples.

We offer technical service in fans for electronic purposes. The assistance of our engineers is readily available.

Eleven sizes of *Aerofoil* fans are available: 4¾ in. to 48 in. diam., in geometric progression. The fans and motors are made completely in our works, backed by 44 years' experience.

Aerofoil FANS

FAN PROBLEMS ANSWERED. You will find a mass of helpful information on all aspects of fan design and performance, system resistance, cooling, etc., in *Woods Practical Guide to Fan Engineering*. 227 pages, 143 diagrams and illustrations, 61 tables, 33 charts, 9″ x 6″. Strongly recommended by the technical press. Price post free 10/6.

WOODS OF COLCHESTER LTD., Braiswick Works, Colchester.

Fan manufacturers since 1909. **AN ASSOCIATE COMPANY of THE GENERAL ELECTRIC CO. LTD. of ENGLAND**

MAGNETIC MATERIALS Extensive research and manufacturing facilities have established Mullard as the leading producers of magnetic materials. They were the first, for example, to introduce Ferroxcube, the world's most efficient magnetic ferrite; 'Ticonal' anisotropic permanent magnets, renowned for their high stability and high energy output; and Magnadur, an entirely new type of permanent magnet with the insulating properties of a ceramic.

The wealth of experience gained from these developments is available to all users of magnetic materials through the Mullard advisory service. An enquiry to the address below will put a team of specialised engineers at your disposal.

Mullard **Mullard**

'TICONAL' PERMANENT MAGNETS · MAGNADUR (Formerly Ferroxdure) PERMANENT MAGNETS · FERROXCUBE MAGNETIC CORE MATERIAL

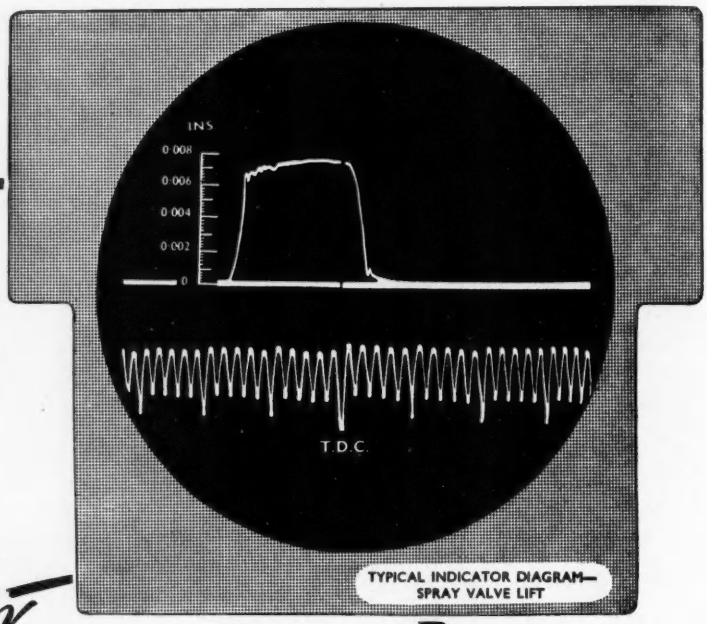
MULLARD LTD., COMPONENT DIVISION, CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2.

Mullard Magnadur permanent magnets ready for firing

The

STANDARD-SUNBURY electronic engine indicator

for



TYPICAL INDICATOR DIAGRAM—
SPRAY VALVE LIFT

Engine Speeds : 80 to approximately 22 000 r.p.m.
Cylinder and Fuel Line Pressures: up to approximately 10 000 lb/sq in. **Torsional Vibrations :** to approximately 60 000 c.p.m.

Bulletin C/IT-11 on request to :—

Produced in association with
THE ANGLO-IRANIAN OIL CO. LTD.
since 1935

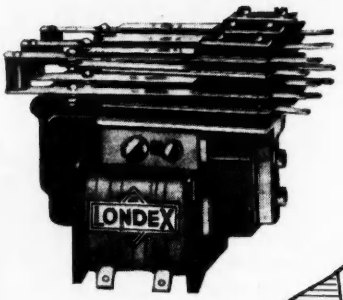
STANDARD-SUNBURY engine indicators

continue to meet the most exacting demands for engine research and fuel research in engines.

Standard Telephones and Cables Limited
Registered Office: Connaught House, Aldwych, London, W.C.2

TRANSMISSION DIVISION: NORTH WOOLWICH, LONDON, E.16

LONDEX **RELAYS...**



MANUFACTURED FROM FINEST MATERIALS

•

EACH UNIT SUBJECTED TO COMPLETE MECHANICAL AND ELECTRICAL TEST BEFORE DESPATCH

•

RELAYS IN USE ALL OVER THE WORLD GIVING EVERY SATISFACTION

•

LARGEST RANGE OF RELAYS AVAILABLE IN THE UNITED KINGDOM

•

IN FACT—THE MOST RELIABLE RELAYS AVAILABLE

★ *See our Exhibit at the A.S.E.E. Exhibition at Earls Court*

Write for our DATA Book 144EE which gives general details of all our equipment

...the choice of the ENGINEER!

LONDEX LIMITED . ANERLEY WORKS . LONDON . S.E.20 . Telephone SYDenham 6258

BARE & INSULATED

RESISTANCE WIRES

THE LONDON ELECTRIC WIRE COMPANY AND SMITHS LIMITED — LEW — REGISTERED

for INSULATED WIRES

VACTITE WIRE COMPANY LIMITED — VACTITE

for BARE WIRES

EUREKA & VACROM

EUREKA REGD. (CUPRO-NICKEL)

VACROM REGD. (NICKEL-CHROME)

'Eureka' (Regd.) and 'Vacrom' (Regd.) Resistance Wires can be supplied BARE or with STANDARD COVERINGS of cotton, silk, rayon, enamel and glass.

These wires have been used for many years for winding resistances for instruments, control apparatus, etc.

'Eureka' with its low temperature coefficient is always in demand for precision work, while Nickel-Chromes are used where a high resistance is required in a limited space.

Full details gladly supplied upon request

THE LONDON ELECTRIC WIRE COMPANY AND SMITHS, LIMITED
LEYTON, LONDON, E.10.

VACTITE WIRE COMPANY LTD.
75 ST. SIMON STREET,
SALFORD 3, LANCS.

$\sqrt{\cdot 5645^2 + \cdot 8556^2} = 1\cdot 025$ **1 minute CURTA time**

(and it's time you got a CURTA)

Work out for yourself how long it would take you to work this out *without* a calculating machine and you will appreciate *why* it's time you had a CURTA—the handiest, neatest of all aids to quicker answers.
Precision-built for absolute accuracy. Adds, subtracts, multiplies, divides, squares, cubes, extracts square roots. Simple to operate. Light weight. Provided with tens transmission and visible dials throughout, together with a handy reversing lever and split clearance of the product register. **Write or 'phone today for a demonstration.**

CURTA	Model 1.	Capacity 8×6×11	£35 10 0
	Model 2.	Capacity 11×8×15	£45 0 0

The perfect calculating machine for all technicians and executives.

LONDON OFFICE MACHINES LTD LOM

Dept. E.E. TERMINAL HOUSE, GROSVENOR GARDENS, LONDON, S.W.1.
Tel: Sloane 1061, 1626, 3268, 3274

Branch Office: Lombard House, Great Charles Street, Birmingham 3. Tel: Central 1210. Branches also at Glasgow, Manchester, Sheffield, Nottingham, Dublin.

74/9

The N·E·P 2-Channel OSCILLOSCOPE

FOR

visual monitoring and wave-form observation

in measuring and recording rapidly changing pressures and other dynamic phenomena in

industry and medicine

In this A.C. mains-operated oscilloscope, a high-speed electronic switch provides observation of two wave-forms together. The panel accommodates either a detachable viewing hood or a standard oscilloscope camera, and an output socket enables simultaneous operation of a second oscilloscope.

The long-persistence cathode ray tube of latest post-deflection acceleration type gives a sharp, bright blue trace with long yellow afterglow, and there is a four-speed linear internal time-base. A separate vertical-deflection amplifier is used for each wave-form input, with gain and beam-shift controls. Operation from an external time-base is facilitated by a horizontal amplifier.

The stove-enamelled rust-proofed welded steel case and internal screening give complete protection from interference during use in conjunction with other apparatus.

Where Industry and Medicine march side by side

The N.E.P. Oscilloscope is one of the N.E.P. range of measuring and recording apparatus designed for use together or separately. Your inquiry stating YOUR individual needs or for literature and further details will receive prompt attention.

NEW ELECTRONIC PRODUCTS LTD.

9 NEW CAVENDISH STREET, LONDON, W.1. (WELbeck 1421-2)

Contractors to the Ministry of Supply, Ministry of Health, U.S.A.F., etc. A.I.D.-approved

Static Charge

an unseen danger!

The Statigun measures potential gradient in air over the range 0-300kv/ft. Attachments enable insulation resistance up to 10^{13} ohms and surface charge density up to 3×10^{-9} coulombs/cm^2 to be measured.

BALDWIN scientific instruments

The instrument is much used for the investigation of static charges in the textile, plastics, paper, rubber and explosives industries as well as in hospital operating theatres. Further details are given in leaflet No. E123 available on request.

BALDWIN INSTRUMENT COMPANY LTD · DARTFORD · KENT TEL. 2948 (3 LINES)

Is your problem PRESSINGS?

We are designers and manufacturers of Electronic Equipment to customers requirements, and will co-operate fully with research engineers to overcome your problems.

We have our own fully equipped Tool Room

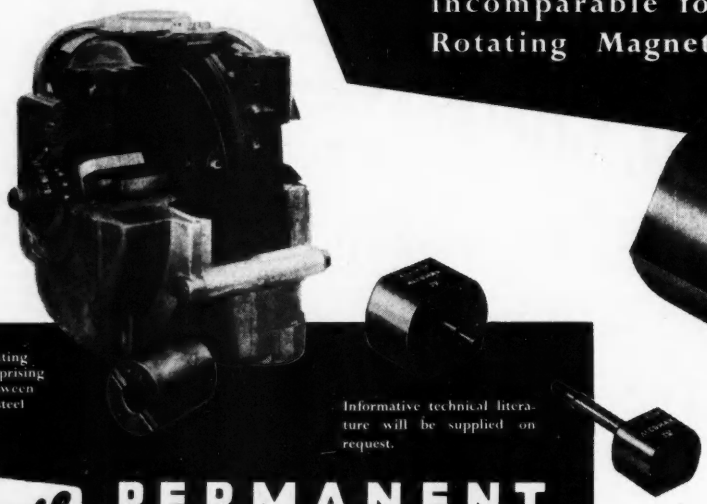
B·P

BARRINGTON PRODUCTS (LEICESTER) LTD.

TELEGRAMS: 'BARPRO' LEICESTER 48, CANK STREET, LEICESTER TELEPHONE: LEICESTER 21328

Alcomax IV

incomparable for Rotating Magnets



Highly efficient rotating magnet system comprising Eclipse magnet between interleaving mild steel pole pieces.

Informative technical literature will be supplied on request.

Eclipse **PERMANENT MAGNETS**

★ Made by the makers of "Eclipse" Permanent Magnet Chucks

JAMES NEILL & CO. (SHEFFIELD) LTD.

SHEFFIELD 11 ENGLAND

M2

TWIN STABILISED POWER UNIT

Check these

Features

on EACH side :

- ✓ 180-350v. D.C. STABILISED. 180mA. RIPPLE : 8mV AT MAX. LOAD
- ✓ 400-450v. D.C. UNSTABILISED
- ✓ 170v. D.C. STABILISED NEGATIVE 2mA
- ✓ 4/6.3v. 3A A.C. EARTHY
- ✓ 4/6.3v. 3A A.C. ISOLATED

This is the only twin Power Unit on the market housed on one 19 in. panel. The two units can be used independently, in series, in parallel, or can be supplied with a self-balancing centre tapped source, one adjustment automatically sets equal positive and negative voltages for use with D.C. Amplifiers, etc.

TWIN STABILISED UNIT **£123** (Ex-Works) SINGLE STABILISED UNIT **£69**

FOR EARLY DELIVERY **ORDER NOW**

OMICRON (ELECTRONICS) LIMITED

HERMITAGE BUILDINGS, LONGFELLOW ROAD, WALSGRAVE, COVENTRY.

WALSGRAVE-ON-SOWE 2950

Electrical
STAMPINGS
and Magnetic
SCREENS

For Quality in the Core
and efficient Screening

MEA productions in all grades of Silicon and Nickel Iron Alloys remain unequalled. An extensive range of standard tooling running into hundred of patterns paces progress in the ever-expanding field of Electronics.

Your requirements, standard or special, will receive immediate attention.

MEA

The following catalogues are available:—
Transformer and Choke Stampings.
F.h.p. Motor Stampings.
Magnetic Screening Tubes and Cases.
Nickel Iron Alloys Data.
On request to our Head Office. Dept. EH/K.

For Service to Science and Industry throughout the field of Electronics

MAGNETIC & ELECTRICAL ALLOYS LTD.

Head Office: 101-3, Baker St., LONDON, W.1. Welbeck 3381/2
Works: Burnbank, Hamilton, Lanarkshire. Hamilton 932/3/4
MANCHESTER: 33 Byrom St., Deansgate. Blackfriars 5223
BIRMINGHAM: 12 Westwood Road, Sutton Coldfield. Streetly 75868
EH

IS YOUR PROBLEM IN

MICRO VOLTS DOWN TO 10
MICRO-MICRO-MICRO WATTS
MEGACYCLES UP TO 25
MICRO SECONDS TO 0·01 **?**

There is an instrument in the
NAGARD RANGE OF
OSCILLOSCOPES & AMPLIFIERS
which will faithfully display it.

Improved Single and Double Beam 'Scopes with D.C. Amplifiers—now available in Twelve Standard Models with most useful aids for the unusual problem plus versatility in daily laboratory use.

Some Models and Uses—
Transients and Pulses
M105—0·02 μsec. rise
R103—0·04 μsec. rise
Wide Band Sensitivity
P103—2 Mc/s 1·4 mV/cm
F103—1 Mc/s 700 μV/cm
H103—100 Kc/s 140 μV/cm
Double Beam
DA103—For Pulses
DH103—Physiological
DS103—250 Kc/s General Purpose
High Discrimination
2701—Pre-Amplifier
Micro Micro Micro Watts
2502—Electrometer

High Sensitivity Double Beam

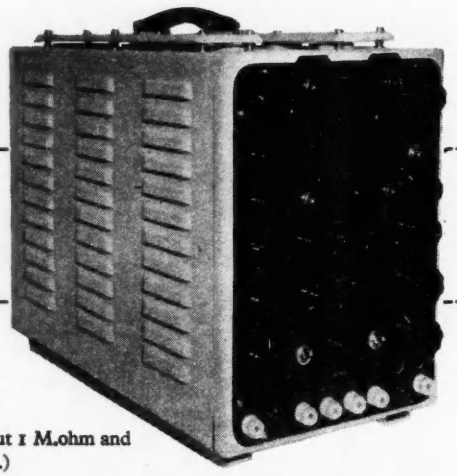
THE NAGARD-UNITEL SYSTEM OF building up various combinations of instruments provides the ideal equipment of exceptional performance yet easily adapted to the next problem—using as the indicator :—CRT Units—1001 Single or 1002 Double Beam. There are time bases and Amplifiers in many useful ranges for use with these CRT Units.

NAGARD LTD

18, AVENUE ROAD, BELMONT, SURREY. VIGilant 0345.
Specialists in Oscillocopes and D.C. Amplifiers.
Your problems are our interest—Write for details.

PHILIPS

Present...



GM 5660 HIGH SPEED OSCILLOSCOPE FOR PULSE, RADAR AND T.V. APPLICATIONS

Features:

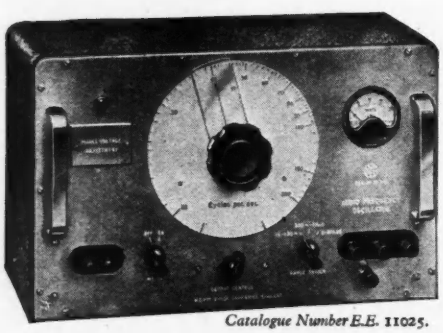
1 Vertical sensitivity 100mVrms/cm.
2 Vertical amplifier 15 c/s—10 Mc/s (-3dB).
3 Amplifier gain 90 X.
4 Vertical input 1 M.ohm and 40 pF (Max.)
5 Built in pulse generator 220-2,500c/s.
6 Time base 2-50,000/u sec. in 5 ranges.
7 Built in post acceleration voltage.
8 Screen 10 cms. diameter.

PHILIPS ELECTRICAL LIMITED

INDUSTRIAL PRODUCTS DEPARTMENT, CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

ARC AND RESISTANCE WELDING PLANT AND ELECTRODES · HIGH FREQUENCY GENERATORS · ELECTRONIC MEASURING INSTRUMENTS
MAGNETIC FILTERS · BATTERY CHARGERS AND RECTIFIERS · LAMPS AND LIGHTING EQUIPMENT · X-RAY EQUIPMENT

(P.I.416)



Catalogue Number E.E. 11025.

AUDIO-FREQUENCY OSCILLATOR

BRIEF SPECIFICATION

Frequency Range.	20 c/s to 20 kc/s in three ranges.
Calibration Accuracy.	± 0.5 c/s up to 50 c/s. ± 1 per cent above 50 c/s.
Distortion.	Not greater than 2 % of maximum output.
Hum Level.	Not greater than 0.2 % of maximum output.
Output.	20 volts into external load of 600 ohms, balanced or unbalanced.
Mains Supply.	200-250 volts, 40-60 c/s.

This instrument employs a resistance-capacitance oscillator circuit, in which the frequency-determining elements have been carefully chosen to ensure stability of calibration. The oscillator section incorporates a control circuit which maintains the output substantially constant at all frequencies. This section is followed by an amplifier and power stage providing an output of 20 volts into an external load of 600 ohms. A surge-limiting circuit is incorporated to prevent sudden mains changes from affecting the output of the oscillator.

Please write for descriptive leaflet

SCIENTIFIC PYE INSTRUMENTS

W. G. PYE & CO. LTD., GRANTA WORKS, CAMBRIDGE, ENGLAND

SEE
HEAR
ADMIRE
at WEBB'S

The ***NEW***
ACOUSTICAL "QUAD. II" *Amplifier*

and unique "QC.II" control unit with push-button selection of record compensation, also any pick-up can be accurately matched by using ingeniously contrived plug-in units. Such conveniences plus reproduction of the highest order makes the "QUAD.II" quite outstanding—an amplifier which is bound to influence future design. Price of amplifier and control unit together is **£42.0.0.** (The control unit "QC.II" costs **£19.10.0** and is applicable for use with the "QUAD.")

The ***NEW***
"REFLECTOGRAPH" *Recorder*

Here is a high fidelity tape recorder of clever electronic design made with engineering precision. It has all the usual facilities like twin-track, recording meter, internal speaker, ALSO CONTINUOUSLY VARIABLE SPEED AGAINST CALIBRATED DIAL—HIGH AND MEDIUM GAIN MICROPHONE INPUTS—OUTPUT FOR EXTERNAL AMPLIFIER—PLUS TRUE "HI-FI" REPRODUCTION.

Before buying a tape recorder we earnestly advise you to hear the Reflectograph at Webb's. The "Standard" model costs £87.0.0. and special models are available for scientific and schools use.

The ***NEW***
COLLARO "STUDIO" *Turnover Crystal Pick-up*

Gives about the best reproduction we have heard from any pick-up with a reasonably large output. Plays L.P. and 78 records with the convenient turnover device. Price including Purchase Tax **£3.14.8.**

The ***NEW***
EDDYSTONE "770 R" *VHF Receiver*

Covers 19 to 165 megacycles by rotating turret in six wave-bands. This quite unique receiver is designed primarily for the professional user and fulfils the long-felt want of the communications engineer for a VHF set of wide frequency coverage. Commercial and official requirements take almost the entire output, but an occasional receiver can be allocated for private sale at **£195.0.0.** A receiver is on demonstration at 14 Soho Street, W.1.

THE NEW 1954 RANGE OF EDDYSTONE COMPONENTS ARE NOW AVAILABLE, fully detailed in the new Eddystone illustrated component catalogue, 1s. post free. (Webb's registered catalogue holders are receiving details by post.)

SEE, HEAR AND ADMIRE THE LATEST AT

WEBB'S Radio

14 SOHO STREET, OXFORD STREET, LONDON, W.1

Tel.: GERrard 2089. Shop Hours: 9 a.m.—5.30 p.m. Sats. 9 a.m.—1 p.m.

ALL ITEMS ARE AVAILABLE FROM STOCK

It's small — yet completely RELIABLE

The illustration shows the 5 amp fuse unit, and indicates the small and compact dimensions which render them ideally suitable for use in instruments where interior space is very restricted. Where vibration is experienced, the Slydlok positive contacts ensure perfect continuity. Cable connections available for every requirement and adaptable for the use of cartridge or neutral links.

SLYDLOK

THE VIBRATION PROOF FUSE

Write for full details of this and other fuses in the Slydlok range.

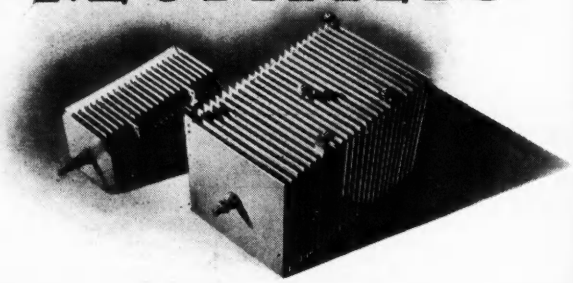
EDWARD *Wilcox* & CO. LTD

WYTHENSHAWE · MANCHESTER

Telephone : WYThenshawe 2235/6/7
Telegrams : "Slydlox" Manchester

dm EW 45

G.E.C. SELENIUM RECTIFIERS



Full particulars of the G.E.C. range of Selenium Rectifiers are available on application to your nearest G.E.C. Branch; E.S. & V. Department, Magnet House, Kingsway, London, W.C.2 : or the address below:

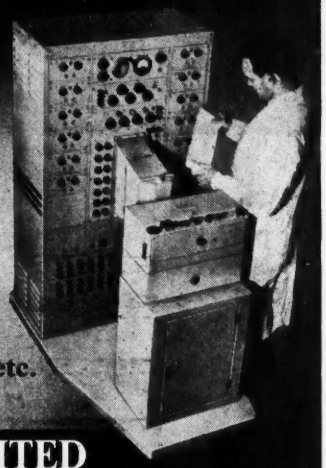
LOW FIRST COST · MAXIMUM STABILITY · LONG LIFE
HIGH EFFICIENCY · NO MAINTENANCE · COOL RUNNING

SALFORD ELECTRICAL INSTRUMENTS LTD · SALFORD 3 · LANCS
A SUBSIDIARY OF THE GENERAL ELECTRIC CO. LTD. OF ENGLAND.

MINIRACK

OSCILLOGRAPHS

For recording any rapid electrical or physical phenomena



★ Single and multi-channel Recorders

★ Specialised F.M. and D.C. amplifiers

★ Recording cameras of all types

★ Capacity, Inductance and Resistance Pick-ups for measuring Pressure, Force, Vibration, Acceleration etc.

Please write for New Catalogue

SOUTHERN INSTRUMENTS LIMITED

CAMBERLEY SURREY

Telephone : Camberley 1883-4

Telegraphic Address : " Minrak," Camberley, England

Electrical Standards for Research and Industry

Testing and Measuring Apparatus for Communication Engineering

Unapproached throughout the world for design and accuracy

WAVEMETERS

OSCILLATORS

CONDENSERS

INDUCTANCES

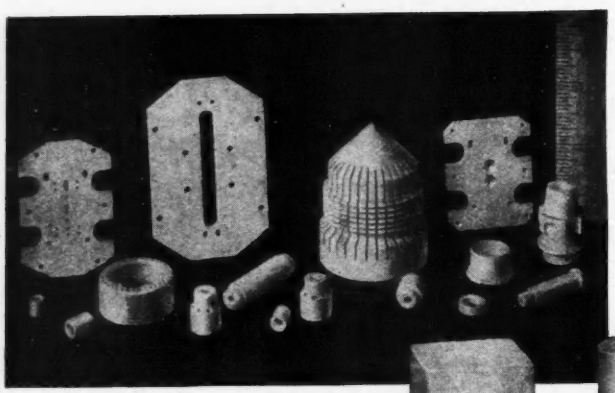
RESISTANCES

BRIDGES—Capacitance, Inductance, Resistance

H. W. SULLIVAN LIMITED

LONDON, S.E.15

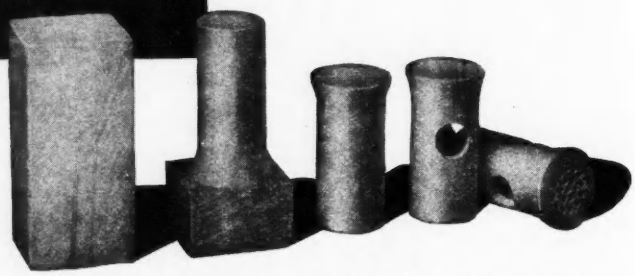
Telephone: New Cross 3225 (P.B.X.)



STEATITE

... for all high frequency applications

Over a century of experience in this highly specialised field. We invite your enquiries.



Machined to special designs and fine limits.

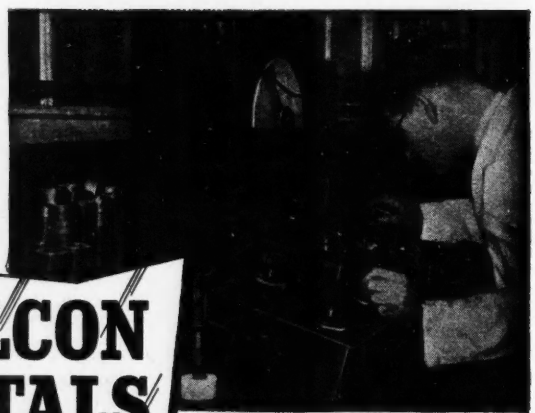
SUGG WESTMINSTER

WILLIAM SUGG & COMPANY LIMITED

RANELAGH WORKS, CHAPTER STREET, WESTMINSTER, S.W.1. VICtoria 3211

Technical Control

Close technical control of production is an all-important factor in the manufacture of Telcon Metals. Accurate tests and measurements are made at various stages in the course of production and the illustrations show two of the many routine examinations conducted in our well-equipped laboratories.



Precision measurement of magnetic characteristics of toroidal Mumetal cores by the Ferrometer.

Routine Factory testing of Mumetal toroidal cores.

TELCON METALS

MAGNETIC ALLOYS — Mumetal, Radiometal, H.C.R., Rhometal, Permendur, R2799, 36/64, Dust.

RESISTANCE ALLOYS — Pyromic, Calomic, Telcuman, Telconstan, Telconal.

SPECIAL ALLOYS — Thermostatic Bimetals 140, 400, 15, Telcoseal, Invar, Beryllium-Copper.

TELCON

The Telegraph Construction & Maintenance Co. Ltd

Head Office: 22 Old Broad Street, London, E.C.2
Telephone: LONdon Wall 7104

Enquiries to: Telcon Works, Greenwich, London, S.E.10
Telephone: GREenwich 3291

EGEN

MINIATURE POTENTIOMETERS

Designed to meet the demand for Egen reliability within the smallest possible compass, these exceptionally small carbon potentiometers (¾" diameter) retain all the desirable features of their standard-size counterparts. The special Egen carbon deposition process ensures a highly stable resistance element of extreme durability.
Double-contact rotor provides firm balanced contact with exceptional freedom from wear and noise. Positively located soldering tags, silver plated for easy soldering. All steel parts rustproofed.
Standard resistance values available, from 5000 ohms to 2 megohms.

Type 105 is identical to Type 115 except that a 2-pole Q.M.B. switch is incorporated.

TYPE 105

PRE-SET RESISTORS
A wire-wound pre-set resistor for panel or chassis mounting

SUB-MINIATURE VOLUME CONTROLS
For use in Deaf Aids and other miniature electronic apparatus

Export enquiries welcomed

EGEN

POTENTIOMETERS

EGEN ELECTRIC LTD., CHARFLEET INDUSTRIAL ESTATE, CANVEY ISLAND, ESSEX • PHONE: CANVEY 691-2

Follow this man!

He is the 'Bostik' Man whose wide experience of adhesion and sealing in all industries will be of invaluable assistance to you. What he is anxious to do is to give you a realistic picture of how 'Bostik' Adhesives and Sealing Compounds can save you man-hours per job, cut production costs, step up production on efficiency. The 'Bostik' man is a specialist in solving tough problems of adhesion and sealing . . . and some have been very tough nuts indeed. It costs absolutely nothing to call in the 'Bostik' Man. Think what he might save you in production costs and headaches . . .

Bostik

ADHESIVES AND SEALING COMPOUNDS

Write to B. B. CHEMICAL CO. LTD., Ulverscroft Road, Leicester. 'BOSTIK' *is the registered trade mark of* B. B. CHEMICAL CO. LTD.

KEEP UP TO DATE!!
DON'T MISS **YOUR** COPY

NEW TRANSRADIO Publication

NEW

R. F. Connectors

TRANS T RADIO

The *most comprehensive range of* U.S. CONNECTORS outside the U.S.A.

69 standard types constant impedance 50 ohms + 70 ohms
*MX+SM Subminiatures
*BNC Miniatures
*N Microwaves
*83 UHF

TRANSRADIO LTD.
Tel. FRE 4421 (P.B.X)

April 6-8
Radio Component Show / Stand No.120
138A CROMWELL ROAD LONDON S.W.7

You can count on TRUMETER

FOR EVERY COUNTING AND MEASURING OPERATION

TRUMETER

TRUMETER COMPANY LTD.,
MILLTOWN • STREET
RADCLIFFE • LANCASHIRE.

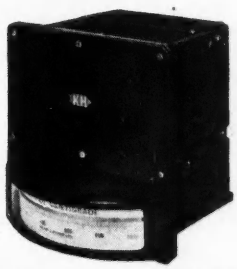
1953.

A TIGHTER REIN ON

TEMPERATURE

These new KH Electronic Controllers keep an accurate and selective control over process temperatures, enabling the smaller industrial organisation to reap the benefit of sensitive control without adding to normal maintenance personnel. Cost and servicing difficulties have been reduced by using a standard chassis and unit construction on five different instruments.

The range covers everything from the straight-forward two-position types to the proportional controller with reset programme control. All are designed to protect the plant in the event of a failure.
May we send you more particulars?

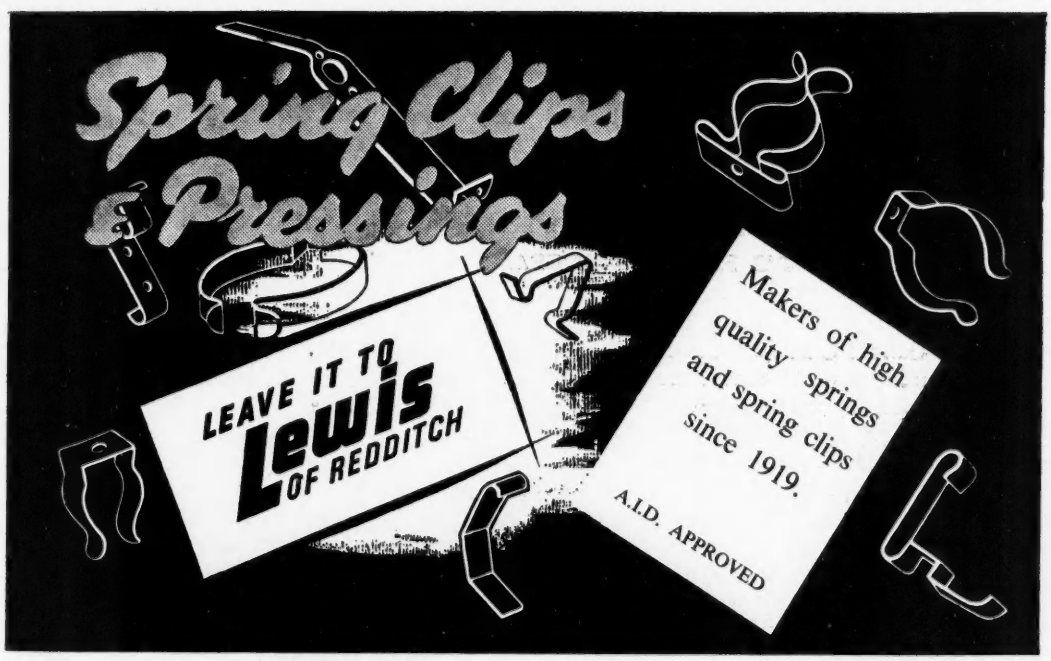


KH KELVIN HUGHES

SPECIALISTS IN INDUSTRIAL MEASUREMENT

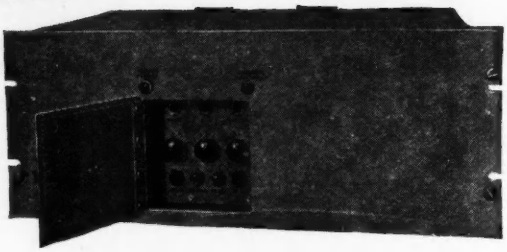
KELVIN & HUGHES (INDUSTRIAL) LTD · 2 CAXTON STREET · LONDON · SW1
110 Bothwell Street, Glasgow, C.2

KH32


Spring Clips & Pressings
LEAVE IT TO Lewis OF REDDITCH
Makers of high quality springs and spring clips since 1919.
A.I.D. APPROVED

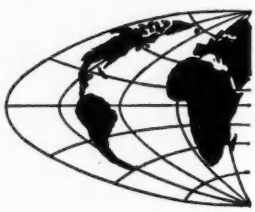
The Lewis Spring Co. Ltd., (Springs, Spring Clips, Presswork, Wire Forms)
Resilient Works, Redditch. Tel.: Redditch 720/1/2
London Office: 321 High Holborn, W.C.1. Tel.: Holborn 7470 and 7479

The Ideal Receiver for Point-to-Point and Ground-to-Air Channels



A Fixed Frequency, Single Channel Receiver covering 2 to 20 Mc/s.

The crystal-controlled R.93 is an important receiver which has been designed to operate over long periods under either temperate, arctic or tropical conditions at unattended sites. A number of R.93's may be stacked in standard 19" racks for multi-channel working on R.T. or W.T. Double or triple diversity racks can also be supplied with suitable terminal equipment for direct teleprinter operation from frequency shift transmission. Enquiries will receive immediate attention.



REDIFON LIMITED
RADIO COMMUNICATIONS DIVISION
BROOMHILL ROAD
LONDON, S.W.18
'Phone : VANDYKE 7281

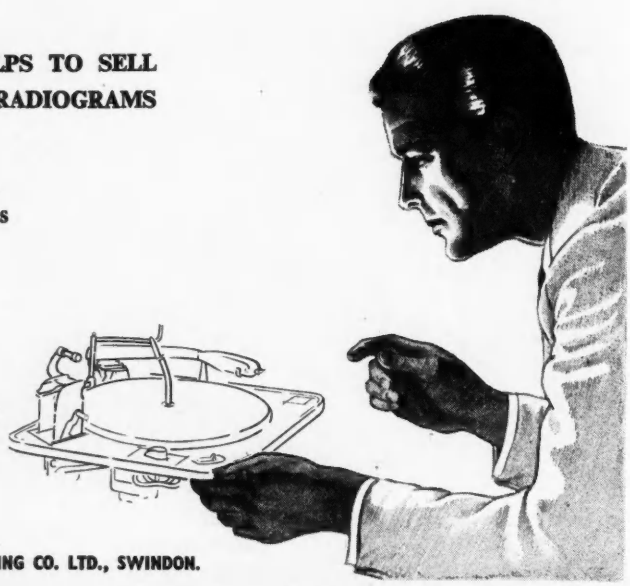
Redifon

DESIGNERS AND MANUFACTURERS OF RADIO COMMUNICATIONS AND INDUSTRIAL ELECTRONIC EQUIPMENT

Garrard

THE NAME WHICH HELPS TO SELL THE WORLD'S FINEST RADIOGRAMS

Garrard Gramophone Equipment is world famous for its reliability and its excellent design, and is acclaimed throughout the world for its superb performance.



All Garrard Record Changers play 7 inch, 10 inch and 12 inch records at 33 1/3, 45 and 78 revolutions per minute.

THE GARRARD ENGINEERING AND MANUFACTURING CO. LTD., SWINDON.

HADDON

FULLY A.I.D. APPROVED

TRANSFORMERS LTD.

27-37 MASONS AVENUE,
WEALDSTONE, MIDDX.

Telephone :
HARROW 9022/3/4/5.

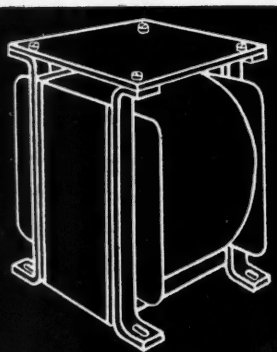
POWER and AUDIO FREQUENCY TRANSFORMERS up to 25kVA.

Open or Enclosed Types—Suitable for all climatic conditions

CONTRACTORS TO ALL GOVERNMENT DEPARTMENTS

SOMERFORD TRANSFORMERS AND CHOKES

A range of 360 standard types available for "off the shelf" delivery in several different mounting styles including both open and hermetically sealed "C" cores.

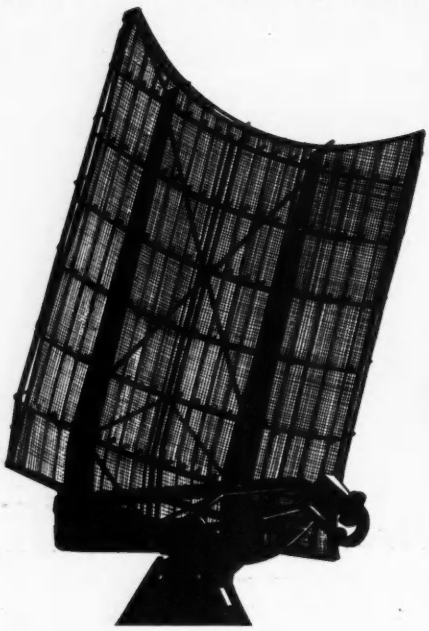


Fully descriptive Catalogue upon request :

GARDNERS RADIO Ltd

SOMERFORD CHRISTCHURCH HANTS *Tel : 1024/5*

MAXIMUM RESISTANCE TO CORROSION • STRENGTH • NON-MAGNETIC



TURBINE BLADING
TRANSFORMERS
OUTDOOR STRUCTURES
SWITCH FARMS
TRANSMISSION
SWITCH GEAR
RADAR EQUIPMENT

The corrosion-resistance, non-magnetic properties and mechanical strength of "Staybrite" steels are solving major problems for the electronic engineer just as they have for specialists in the fields of power generation and distribution. Examine the unique features of the "Staybrite" family of steels against your problem.

FIRTH-VICKERS

"Staybrite Steel"

IDEAL METAL FOR ELECTRICAL APPARATUS IN THE NEW FIELDS AS IN THE OLD

FIRTH-VICKERS STAINLESS STEELS LTD., SHEFFIELD
Telephone No. Sheffield 42061

FERGUSON RADIO CORPORATION LTD.

HAVE VACANCIES FOR

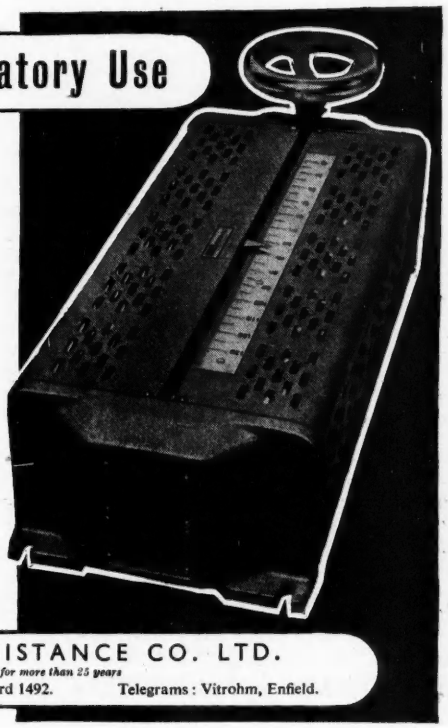
SENIOR ENGINEERS with initiative and sound technical background for work on a wide range of projects in the field of Electronics including Television, Radio, Communications and Test Equipment. Permanent posts for men able to carry responsibility in rapidly expanding departments offering exceptional promotion and long term prospects.

JUNIOR ENGINEERS of ability for work on Development Projects offering a wide experience in the fields of Television, Radio, Communications and Test Equipment with excellent prospects for advancement.

Vacancies exist in Laboratories situated both at Enfield and Spennymoor, Co. Durham. These Laboratories are well equipped and working conditions excellent. Successful applicants eligible for Company's Pension Scheme. Housing assistance considered in appropriate cases.

Applications specifying the post for which application is made and giving full particulars as to age, qualifications and experience, etc., to **Employment Manager, Ferguson Radio Corporation, Ltd., Great Cambridge Road, Enfield, Middlesex.**

For Industrial and Laboratory Use



All types of A.C. apparatus—motors, furnaces, rectifiers, transformers—can be controlled by a single Regavolt whose output can be set, regardless of the load current, precisely at any voltage from 0 to 30% above the supply. Its rugged design for heavy industrial duty ensures reliability under severe working conditions.
Special designs can be made for incorporation in your own apparatus in addition to the wide range of single, 3 phase, hand and motor driven models listed in our catalogue No. 3131.

HIGH EFFICIENCY—
COMPETITIVE PRICE

BERCO

"REGAVOLT"
REGULATING TRANSFORMER

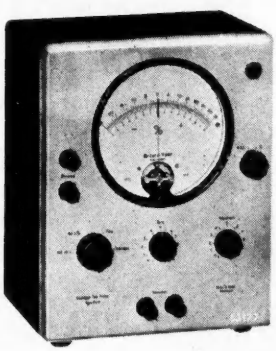
THE BRITISH ELECTRIC RESISTANCE CO. LTD.
Specialists in the control of current and voltage for more than 25 years
Queensway, Ponders End, Middlesex. Telephone : HOWard 1492. Telegrams : Vitrohm, Enfield.

BR3131/T

DEVIATION TEST BRIDGE

Type 1502 and 1507

Extremely fast, direct reading, impedance measuring instrument.



FEATURING:

Production tests at a rate of 4000 an hour.

Accuracy exceeding 0.1 % at zero point center scale and 5 % of full scale.

A large six inch illuminated meter scale, very easily read.

A very high stability, making it unnecessary to recalibrate more than once a day.

Insensitive to hum voltages, due to a demodulator in the circuit.

Perfect safeguard against overload.

This bridge is designed to present accurately a comparison with an arbitrary external standard impedance, indicating on a large scale the percentage deviation.
Each instrument contains two arms of a Wheatstone bridge internally, the two other bridge arms having external terminals for the standard and the sample to be tested. The bridge is fed from a built-in oscillator with 1000 c/s for type 1502 and 50.000 c/s for type 1507 as test frequencies. The diagonal voltage is amplified and led to a demodulator circuit, together with the generator voltage, and a d.c. meter in this circuit indicates the deviation.

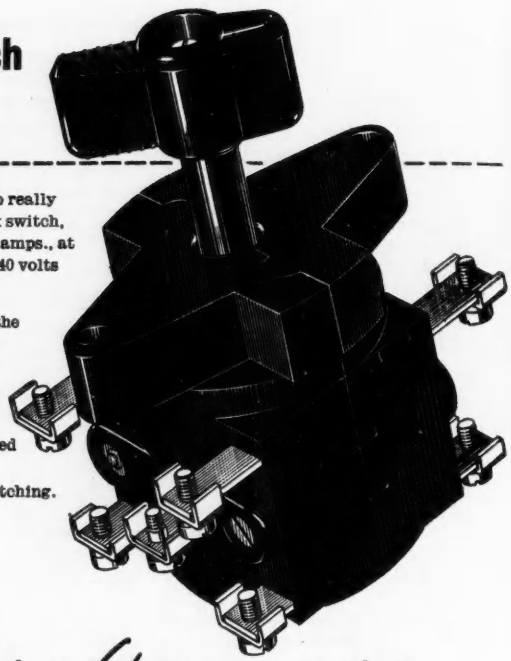
B K

Brüel & Kjær

Adr. Nærum, Denmark . Telephone: Nærum 500 . Cable: Brukja, Copenhagen

LONDON OFFICE: ROCKE INTERNATIONAL LTD., 59 UNION ST., S.E.I. Phone: HOP 4567.

A quality multi-purpose switch
for only 10/6



At last a compact, low priced rotary switch which will stand up to really heavy use. The Austinlite "TENAMP" is a slow make-and-break switch, capable of handling loadings up to 10 amps., at 250 volts A.C., or 5 amps., at 440 volts A.C. Fractional horse power motors up to ¾ H.P. 230 or 440 volts A.C., can also be switched by it.

Fully maintaining every Austinlite quality, special features are the spring loaded roller mechanism ensuring immediate and positive location; wiping type line contacts with pressure exerted by an independent contact spring and a reversible handle for alternative mounting on panels of ¼" thickness up to ½".

Wiring instructions for 18 different circuit applications are supplied with each switch. These include:—

Three phase motor reversing. Three heat series/parallel switching.
Capacitor motor starting. Series motor reversing.
S.P. 4 way tapping. D.P. ON/OFF.
D.P. changeover.

Write for illustrated leaflet.

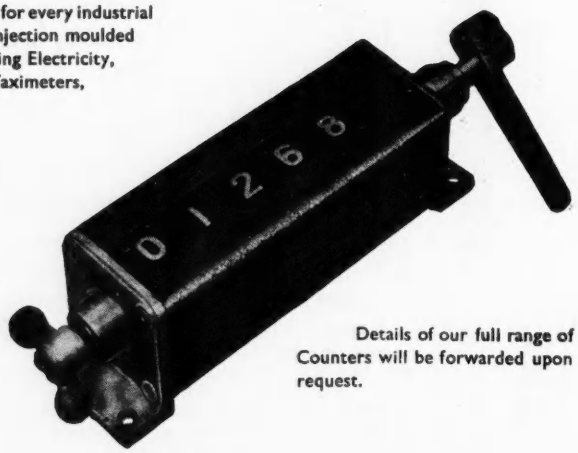
The Austinlite Tenamp switch is a Chance product

AUSTINLITE LIMITED, DEPT. A.5., LIGHTHOUSE WORKS, SMETHWICK 40, BIRMINGHAM. TEL: WEST BROMWICH 1824.

FROM NUMBER WHEELS TO COUNTERS

We specialise in the manufacture of Counters for every industrial application. Number Wheels and Pinions injection moulded in tin alloys or plastics for use in direct reading Electricity, Gas, Water Meters, Telephone Registers, Taximeters, etc., are also available.

Details of Number Wheels and Pinions on request.



Details of our full range of Counters will be forwarded upon request.

COUNTING INSTRUMENTS LTD.

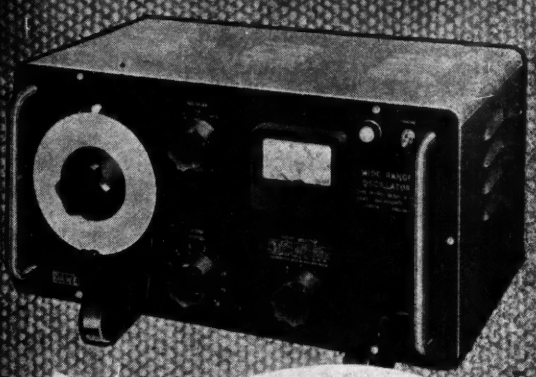
5, ELSTREE WAY, BOREHAM WOOD, HERTFORDSHIRE Telephone: ELSTREE 1382-3-4

DAWE

Wide Range OSCILLATORS

A series of resistance-tuned oscillators of low distortion

TYPE 400A : 20 c/s — 20 kc/s 1 watt output
TYPE 400B : 20 c/s — 200 kc/s 100 mW output
TYPE 400C : 0.1 c/s — 1000 c/s 100 mW output



NOW AVAILABLE FOR PROMPT DELIVERY!

Technical data from: DAWE INSTRUMENTS LTD., *Instrument Division*
99 UXBRIDGE ROAD, EALING, LONDON, W.5 · EALING 6215
or from your Regional Agent

Midlands	North of England	Cheshire	Scotland	West of England	Northern Ireland
Hawnt & Co., Ltd., 59, Moor Street, Birmingham, 4 *Central 6871*	A. C. Farnell, Ltd., 15, Park Place, Leeds, 1 *Leeds 32958*	F. C. Robinson & Ptnrs., 287, Deansgate, Manchester, 3 *Deansgate 6601*	Land, Speight & Co., 73, Robertson Street, Glasgow, C.2 *Central 1082*	Radford Electronics, Ltd., 4, Acraman's Road, Bristol, 3 *Bristol 64300*	James Lowden & Co., 11 Middlepath Street, Belfast. *Belfast 57518*

NEW *MEDIUM-SPEED* PLOTTING TABLE

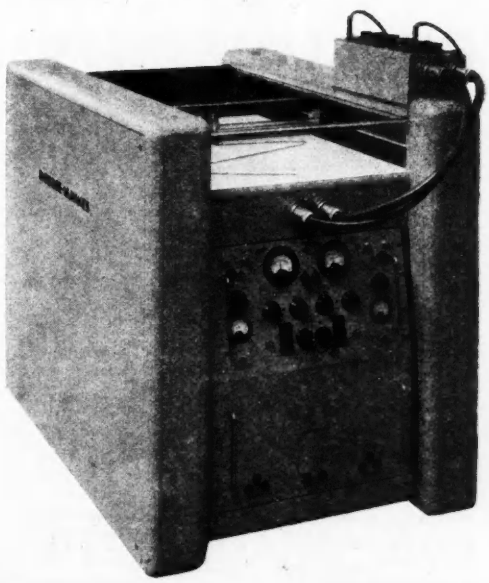
A mains-operated general purpose instrument for plotting the relationship between any 2 variables at rightangles (X, Y co-ordinates).

It is **self-contained** and rapidly records directly on **30 in. × 18 in.** paper.

Meticulous care has been given to Accuracy, Ease of Operation and Setting up.

•

For very high speeds, the Dobbie McInnes 'Ferranti' High-Speed Recorder is recommended.



DOBBIE McINNES LTD. BROOMLOAN ROAD, GLASGOW, SCOTLAND.

IT is admitted that the present reception of the BBC's medium and long wave transmissions is most unsatisfactory in many parts of the country.

The BBC is proposing to remedy these conditions by erecting a chain of some 51 V.H.F. stations, and it is almost certain that F.M. will be the type of modulation chosen.

The principle of Frequency Modulation technique is discussed fully in :—

"Frequency Modulation"

By K. R. STURLEY, Ph.D., M.I.E.E.

Price **2/6** (postage 2d.)

The construction of a suitable receiver for the existing F.M. transmissions from Wrotham is described in :—

"A Home-Built Frequency Modulated Receiver"

By K. R. STURLEY, Ph.D., M.I.E.E.

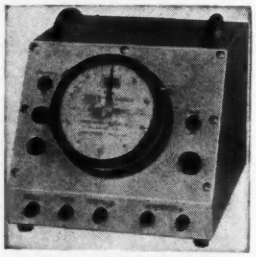
Price **4/6** (postage 3d).

These and other monographs are obtainable from

28 ESSEX STREET, Electronic Engineering STRAND, LONDON, W.C.2

EQUIPMENT FOR
RESEARCH
AND
DEVELOPMENT

★ Vibration Equipment
★ High Speed Electric Counters.
★ Strain Gauge Equipment
★ High Accuracy Tachometers
★ Temperature Measuring Equipment



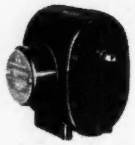
NEOSTRON COUNTING UNIT
Valve-triggered counting unit, incorporating D.W.A. High-Speed Pulse Register, for accurate timing applications where the instrument counts tuning fork oscillations, or any other rotary or oscillating motions using photo-electric or other pick-ups.

DAVIS, WYNN & ANDREWS LTD
SCIENTIFIC EQUIPMENT
DWA
CHELTENHAM ENGLAND
TELEPHONE 53606 TELEGRAMS "INVENTION"
K/DWA. .I

DRAYTON
FRACTIONAL H.P. MOTOR UNITS

The DRAYTON R.Q. is a miniature capacitor induction type motor with a current consumption at 230 volts, 50 cycles of 0.09 amps pf. 0.9. It is available:

RQG GEARLESS
Running at 2,700 r.p.m. continuously or intermittently in either direction or continuously reversed.



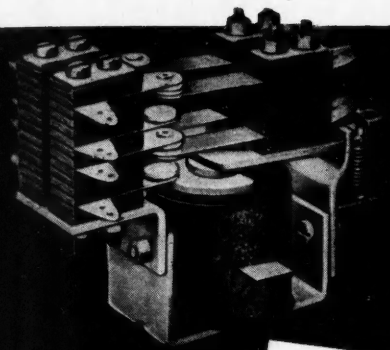
RQR GEARED
For continuous or intermittent running or reversing at speeds from 27 mins. per rev. to 600 revs. per min., with or without self-switching up to 2 1/3 r.p.m.

RQH GEARED
For high final shaft speeds for continuous or intermittent running, forward or reverse.

for
actuating valves, dampers, rheostats, geneva movements, rocking baths, flashing signs, illuminated models, soldering and welding fixtures, rotating tables, automatic light strip feed, lubricating and other small pumps, small machines, animated displays, vibrators, developing baths, agitators, fans, aspirators, etc.

Send for List No. M. 302-1 RQ13
The Drayton Regulator & Instrument Co. Ltd., West Drayton, Middlesex

Precision RELAYS



- 1-, 2- or 4-pole AC/DC change-overs
- pneumatic time delays
- mechanical time delays
- for temperature control

AVAILABLE IN STANDARD RANGES OR MADE TO ORDER

TEMPERATURE & HUMIDITY CONTROLLERS

- CONTACT THERMOMETERS
  fixed or adjustable
  Range: −30° to +600°C
- CARTRIDGE THERMOSTATS
  Range: −100° to +600°F
  5 amp rating 250 volts AC

PROMPT DELIVERY

ELECTRO METHODS LTD
OF STEVENAGE

—THE FIRST NAME FOR
HIGH-STABILITY MAGNETIC AMPLIFIERS
and LOW-INERTIA INTEGRATING MOTORS

Full data from **ELECTRO METHODS LTD. Division RT 20**
CAXTON WAY, STEVENAGE, HERTS. Stevenage 780

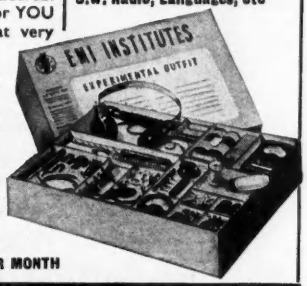
NEW!
EXPERIMENTAL OUTFITS

LEARN THE PRACTICAL WAY!

Whether you are a student for an examination, starting a new hobby, intent upon a career in industry or running your own business — these Practical Courses are intended for YOU — and may be yours at very moderate cost.

With these Outfits, which you receive upon enrolment, you are given instructions which teach you in easy stages the basic principles of the subject concerned. A tutor gives individual help and guidance throughout the Course.

COURSES WITH PRACTICAL EQUIPMENT INCLUDE: Radio (Elementary & Advanced), Television, Mechanics, Electricity, Chemistry, Photography, Carpentry. Also Draughtsmanship, Commercial Art, Amateur S.W. Radio, Languages, etc



EASY TERMS FROM £1 PER MONTH

E.M.I. INSTITUTES
The only Postal College which is part of a world-wide industrial organisation.

POST THIS COUPON TODAY

Please send me your FREE book on Practical Courses:

I am interested in .....

To: E.M.I. INSTITUTES, Dept. 11x, 43, Grove Park Road, Chiswick, London, W.4.

NAME .....

ADDRESS .....

.....IC24

Electronic *Equipment*

Positive re-action to all your enquiries.

Over a number of years Evans Electronic Developments Limited, have maintained an outstanding lead in the field of specialist and prototype production of electronic equipment.

Constant research and development utilising the most modern methods have enabled us to produce a wide variety of products. Can we help you? We will prepare to your specifications or design complete units.

EVANS ELECTRONIC DEVELOPMENTS LIMITED

Evonic Works, Birchfield Rd., Birmingham, 19

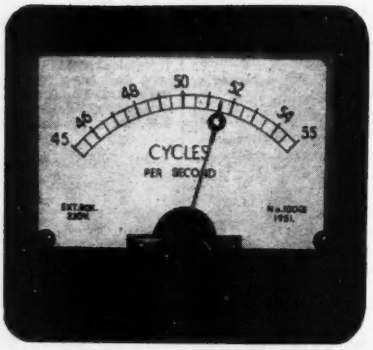
Northern 0792.

7353

FREQUENCY METERS

UP TO 5000 CYCLES

PROMPT DELIVERY



also the new **SYNCHROSCOPE**
M.C. KILOVOLTMETERS
and full range of Switchboard Instruments.

Ask for illustrated Catalogue

THE ELECTRICAL INSTRUMENT CO. (Hillington) LTD.
HILLINGTON, GLASGOW
London stockists, H. A. Patterson, 156 High Holborn.

Graham Gear Co Ltd

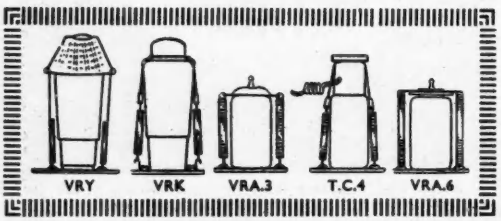
SPURS
SPIRALS
BEVELS
8-100 D.P.

STATION ROAD
BROOKMANS PARK, HERTS.
Tel:- HATFIELD 3130

Unique range of valve retainers for all types of electronic equipment

THE wide range of valve retainers available from **ELECTROTHERMAL** Engineering is an example of how we keep "out front" in the electronic component field. **ELECTROTHERMAL** valve retainers can be supplied to fit any type, make or size of valve you use. Some of these retainers are unique. There are **ELECTROTHERMAL** retainers for miniature valves, top-cap valves, transmitter valves, C.R.T.'s, etc. **ELECTROTHERMAL** also produces connecting clips to be used with top-cap valves. We can supply clips to be used without retainers or clips of unique design to be used in conjunction with retainers. For full information and literature phone or write *now* to **ELECTROTHERMAL ENGINEERING LIMITED, 270 NEVILLE ROAD, LONDON, E.7.** (GRAngewood 0055).

Electrothermal for high precision electronic instruments



Electrothermal products are covered by British & Foreign patents

THE NEW

for cheaper radio listening

This new Ever Ready Battery, combining a 90 volt high tension unit and a 1.5v low tension section, has been designed for use with the latest Ever Ready low consumption valves, type DK96, DF96, DAF96 and DL96, which use only half the filament current (25mA) of the older series valves (50mA).

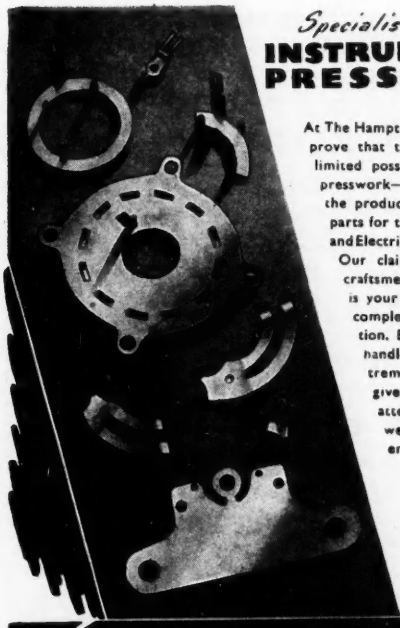
A balanced service life of 300 hours is obtained when the high tension current is 10.5 mA at 90 volts and the low tension current 125 mA at 1.4 volts; the respective cut-off voltages being 40v and 1.0v on load.

The maximum battery dimensions are $7\frac{13}{16}" \times 3\frac{7}{8}" \times 4"$ and the weight is 5 lbs. 10 oz. **Price 16/-.**

BATTERY PLUG

The new Ever Ready plastic 4 pin battery plug has been specially designed to ensure correct and easy battery connections. Plugs are fitted with four staggered metal pins, also four coloured wires 18" in length. List Price 2/- complete. Suitable for use with BSS. 1766-1951.

EVER READY DRY BATTERIES FOR RADIOS TORCHES · HEARING AIDS · CYCLE LAMPS



Specialists in

INSTRUMENT PRESSINGS

At The Hampton Works we prove that there are unlimited possibilities with presswork—especially in the production of small parts for the Electronic and Electrical Industries. Our claim as master craftsmen in pressings is your assurance of complete satisfaction. Every order is handled with extreme care and given prompt attention. We welcome your enquiry.

The HAMPTON WORKS (STAMPINGS) LIMITED
PRESSWORK EXPERTS
TWYNING ROAD, STIRCHLEY, BIRMINGHAM, ENGLAND
Tel: KINgs Norton 2901 (3 lines) Grams: Radiaglitz, Birm

Switch on to HENLEY SOLON

TRADE MARK

ELECTRIC SOLDERING IRONS

Solons save time, reduce costs. Solon soldering is always clean, reliable, and simple. Five models, in voltage range 100–250, each with 6 feet Henley flexible. 65 watt—oval tapered or round pencil bits. 125 watt—oval tapered or round pencil bits. 240 watt—oval tapered bit.

Write for Folder Y.10

W.T. HENLEY'S TELEGRAPH WORKS CO. LTD.
51-53 HATTON GARDEN, LONDON, E.C.1.

THE ARMY EMERGENCY RESERVE

ROYAL ELECTRICAL & MECHANICAL ENGINEERS

VACANCIES FOR QUALIFIED OFFICERS AND OTHER RANKS : PREVIOUS MILITARY SERVICE NOT ESSENTIAL

15 DAYS ANNUAL TRAINING AT FULL ARMY RATES OF PAY AND ALLOWANCES AND FULLY QUALIFIED ELECTRONIC ENGINEER WO's AND SENIOR NCO's CAN OBTAIN, IN ADDITION, UP TO

£50 TAX-FREE BOUNTY

VOLUNTEER FOR 2, 3 OR 4 YEARS AND LEND YOUR SKILL TO

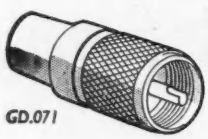
BRITAIN'S RESERVE ARMY

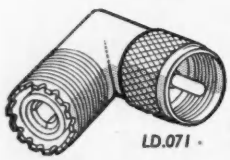
LIABILITY FOR RECALL IN THE EVENT OF GENERAL MOBILIZATION ONLY

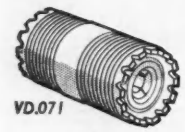
WRITE FOR FULL DETAILS TO

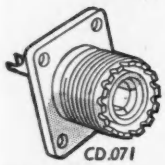
HQ AER REME (SEC. EE)
BROXHEAD HOUSE, BORDON, HANTS
OR ASK AT ANY ARMY RECRUITING OFFICE

SCREENED CONNECTORS


GD.071


LD.071


VD.071


CD.071

RD.07/05

for cables of 0.2″ to 1.03″ O.D.
Single and multi-way types.
Special types fitted with coupling rings.
Cable joining connectors.
U.S. Type Connectors as illustrated.

CABLE O.D.	TYPE	CODE NO.
0.41″	Straight plug	GD.071
0.25″	Reducing adaptor	RD.07/05
0.2″	Reducing adaptor	RD.07/03
fits on GD.071 CD.071 VD.071	Elbow plug adaptor	LD.071
fits on GD.071 LD.071	Bulkhead (Junction) adaptor	VD.071
fits on GD.071 LD.071	Chassis receptacle	CD.071

Other Transradio specialised products:
CO-AX air-spaced articulated Very Low Loss Cables.
Microdual Two-speed Precision Drives.

TRANSRADIO LTD
138A CROMWELL ROAD, LONDON, SW7, ENGLAND
Telephone: FREmantle 4421 (P.B.X.)

MOLYBDENISED LISTATE GREASE*

* the perfect all purpose grease

Molybdenised Listate Grease consists of a special lithium base grease which is fully water repellent, plastic at −40°F, with a melting point of 350°F, reinforced with Molybdenum Disulphide. The grease itself will give adequate lubrication in normal conditions whilst the Molybdenum Disulphide will build up a surface of extremely low coefficient of friction on all working surfaces to ensure efficient lubrication should the grease break down due to such causes as extreme conditions or lack of servicing. The use of Molybdenised Listate Grease will ensure efficient working of all grease lubricated components for a considerably longer period than any other grease.

RAGOSINE

MOLYBDENISED LUBRICANTS

Ragosine Oil

Write for brochure giving full details to :

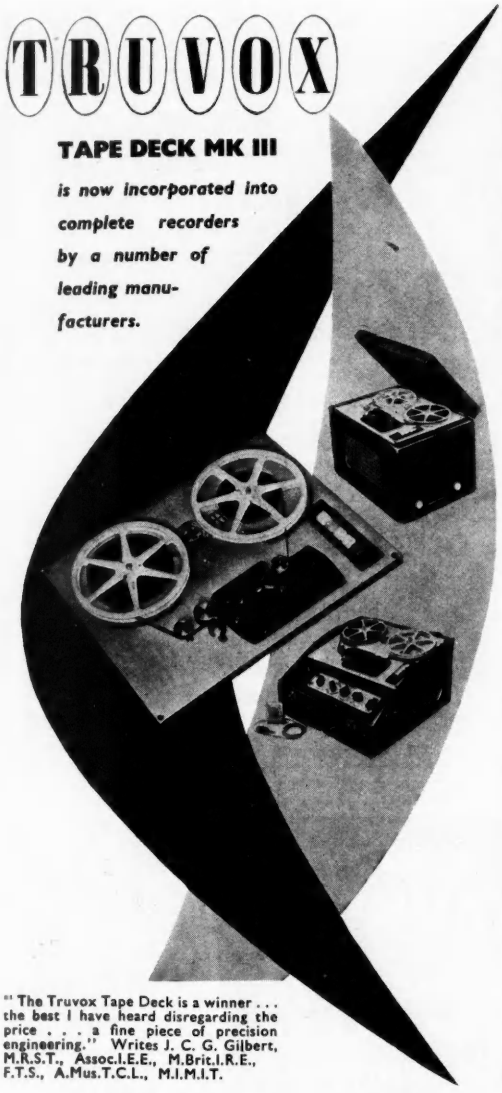
ROCOL LTD.
(A subsidiary of Ragosine Oil Co. Ltd.)
IBEX HOUSE, MINORIES, LONDON, E.C.3
MINERVA WORKS, WOODLESFORD, NR. LEEDS.

n.d.h. 01574/B.

TRUVOX

TAPE DECK MK III

is now incorporated into complete recorders by a number of leading manufacturers.



"The Truvox Tape Deck is a winner . . . the best I have heard disregarding the price . . . a fine piece of precision engineering." Writes J. C. G. Gilbert, M.R.S.T., Assoc.I.E.E., M.Brit.I.R.E., F.T.S., A.Mus.T.C.L., M.I.M.I.T.

"Elpico" Recorder in leatherette cabinet Separate Radio Tuner is available for extending the applications of this instrument. Produced by Lee Products (GB) Ltd.

"Prima" general purpose recorder in streamlined carrying case by Unitelex Ltd. 4 watts output.

WE SHALL BE PLEASED TO PUT INTERESTED ENQUIRERS IN TOUCH WITH THESE MANUFACTURERS.

A TRUVOX PRODUCT

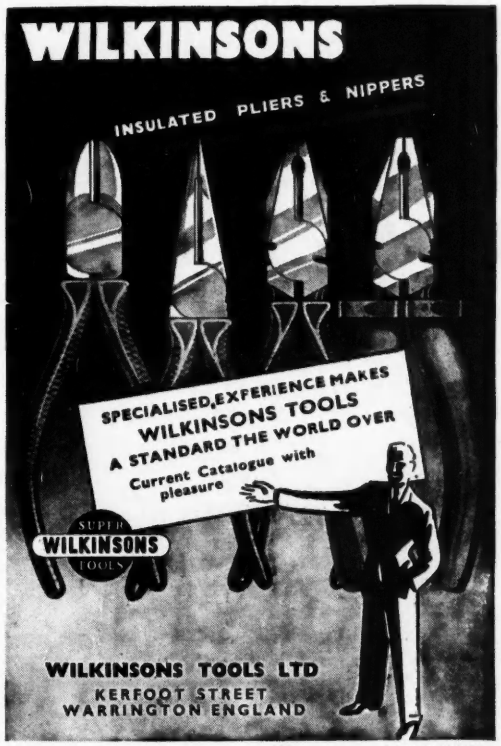
TRUVOX LIMITED

HARROW, MIDDLESEX

Sales Office : 15 Lyon Road, Harrow, Middlesex. *Phone : Harrow 9282*
Service and Technical Depts. : 328 The Broadway, Harrow Road, Harrow, Middlesex. *Phone : Harrow 4455*

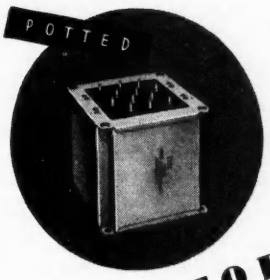
WILKINSONS

INSULATED PLIERS & NIPPERS



WILKINSONS TOOLS LTD
KERFOOT STREET
WARRINGTON ENGLAND

C.W 2415/150



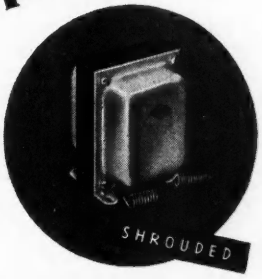
A wide range of capacities and types for both transformers and chokes.

Absolute reliability owing to vacuum impregnation and special compound filling.

Suitable for exacting industrial and climatic conditions.

Neat and clean appearance in equipment.

TRANSFORMERS



Woden shrouded transformers have been developed to give a competitive product combined with a first class engineering job. Finest quality materials used throughout; vacuum drying and vacuum/pressure impregnation, rigidly tested.

A popular, highly competitive line.

WODEN TRANSFORMER CO. LTD.

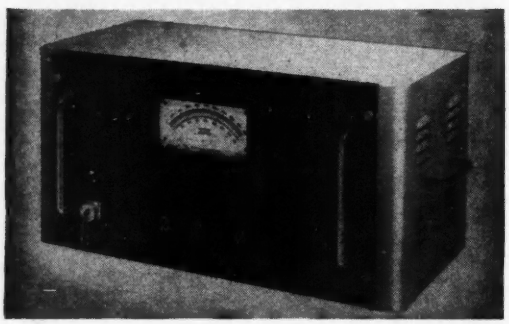
MOXLEY ROAD · BILSTON · STAFFS.

Tel. : BILSTON 41959.

Isotopes in Industry and Research

ISOTOPE DEVELOPMENTS ARE MAKING STANDARD EQUIPMENT

in the Radioactive field



THE E.H.T. SUPPLY UNIT TYPE No. 532

The E.H.T. Supply Unit is a very stable source of high voltage designed for the operation of Geiger-Müller tubes, ionisation chambers and proportional and scintillation counters.

OUTPUT VOLTAGE : Continuously variable over three ranges : 300 - 3000 volts at 3 milliamps.

OUTPUT VOLTAGE REGULATION: Less than 0.05% change for 10% change in mains input voltage; mains frequency variations are included in this regulation.

Output ripple **less than 0.03** volts R.M.S.

OUTPUT IMPEDANCE : Less than 500 ohms.

STABILITY : Short term drift less than 0.1% per 10 hours. Long term drift less than 0.2% per 100 hours.

METER : Five inch first **grade** rectangular scale.

Detailed specifications are available. Our electronics department is at your service on application.

We are exhibiting in the Physical Society Exhibition, Imperial College, London, 8th — 17th April, 1954.

ISOTOPE DEVELOPMENTS LTD

120, MOORGATE, LONDON, E.C.2

Telephone: METropolitan 9641

Midland Agent : **HAWNT & CO. LTD., 59 Moor Street, Birmingham, 4.**

Northern Agent : **A. M. LOCK & CO., Crompton Street, Chadderton, Oldham, Lancs.**

Scottish Agent : **A. R. BOLTON & CO., 72 Haymarket Terrace, Edinburgh, 12.**

LUMINESCENT MATERIALS

FOR

ELECTRIC DISCHARGE LAMPS
CATHODE RAY TUBES
X-RAY SCREENS
INSTRUMENT DIALS
DECORATIVE DISPLAYS

SPECIAL PHOSPHORS MADE TO CUSTOMERS' SPECIFICATIONS

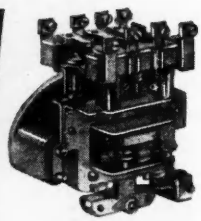
★ ★ ★

DERBY & COMPANY LTD.

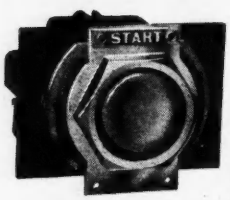
Offices :
11-12 St. Swithin's Lane, London, E.C.4.
Telephone : MINCING LANE 5272.
Telegrams : PLATIVET, London.

Works :
Millmarsh Lane, Brimsdown, Middx. HOWard 2208

DONOVAN ACCESSORIES *for the* ELECTRONIC APPARATUS MANUFACTURER

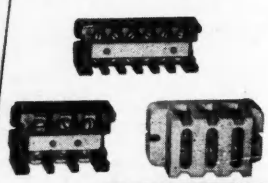


Type A.11 A.C. POWER RELAY—4-Pole with N.O. or N.C. contacts.



Type C.30 PUSH BUTTON UNIT arranged for mounting on customers' own cover plate.

TYPE J.96 TERMINAL BLOCKS



Made in 15, 30 and 60 amp. sizes.

Visit our Exhibit, STAND No. 64 Elec. Engrs'. Exhibition, EARLS COURT,

THE DONOVAN ELECTRICAL CO. LTD.
Safuse Works · Stechford · Birmingham, 9.

CYGNET LABORATORY FURNITURE

"CYGNET" Benches, with heat and acid-resisting tops; Racks, Fume Cupboards, Cabinets and Shelving are made in a large range of standard units or to specification. Complete installations or single pieces for Electronic, Chemical, Physical and other Laboratories at keen prices. Built to meet the most exacting demands.

Recent contracts include installations for :—

Scottish Oils Limited
University of Sheffield
British Nylon Spinners, Pontypool
Revertex Ltd., Harlow, Essex
De Havilland Aircraft Co.
University of Manchester
Ferranti Limited, Edinburgh

THE MARK OF THE CRAFTSMAN

Experience enables us to recommend "FIBROLENE" chemical resistant flooring for laboratories. Send for full details now.

CYGNET JOINERY LTD., Higher Swan Lane, BOLTON. *Bolton 1840/4*

C 2

PHILIPS TECHNICAL LIBRARY

A superb treatise on

Low Frequency Amplification

By Dr. N. A. VOORHOEVE

500 pages. 479 illustrations. **50s.**

Theory, assembly and operation of microphones, amplifiers, recorders and similar devices. Sumptuously illustrated and with copious references, it will be invaluable in all branches of the sound industry.

Industrial Electronics

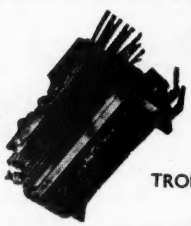
Dr. R. KRETZMANN'S practical book for the works engineer describes typical apparatus for many purposes, with circuit diagrams and photographs. Foreword by Prof. JAMES GREIG, King's College, London. 230 pages. 250 illustrations. **25s.** (*post* 9*d*.)

Television Valves

J. JAGER'S *Data and Circuits of Television Valves*, No. IIIc in Philips Valve Series, is a rich and timely collection of information, with numerous circuit diagrams. 214 pages, 118 illustrations. **21s.** (*post* 9*d*.)

Descriptive Folders free from Distributors :

CLEAVER-HUME PRESS LTD.
London: 31 Wright's Lane, W.8



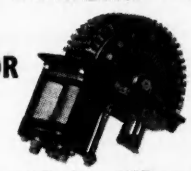
MAGNETIC RELAYS

Built to your Specification

TYPES 3000 and 600

HIGH SPEED and A.C. to 400 VOLTS

TROPICALISING — IMPREGNATING



UNISELECTOR SWITCHES

From 3 to 8 Bank — All Resistances

KEY SWITCHES

Several types in stock

GOVERNMENT CONTRACTORS — SPEEDY DELIVERIES

JACK DAVIS (RELAYS) LTD.

36 PERCY STREET · LONDON · W.1

MUSEUM 7960 LANGHAM 4821

CROYDON PRECISION INSTRUMENT CO.

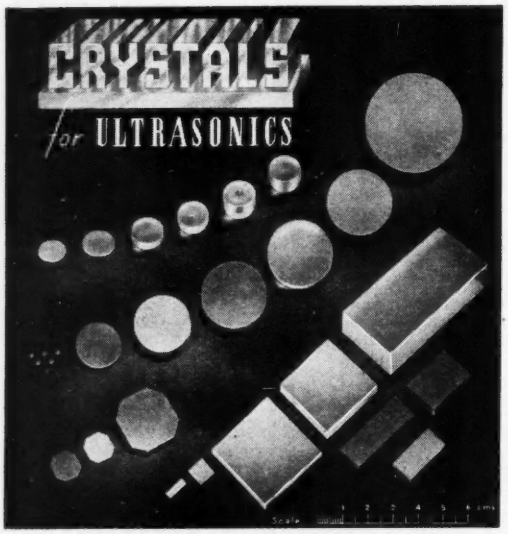
Manufacturers of

VERNIER POTENTIOMETERS
STRAIN MEASURING EQUIPMENT
KELVIN BRIDGE OHMMETERS
PORTABLE POTENTIOMETERS
RESISTANCE STANDARDS
PORTABLE BRIDGES
RESISTANCE BOXES
D.C. STABILISERS
TUNING FORKS
OSCILLATORS

We would also draw your particular attention to our **Wheatstone Bridge Type WSI** which is entirely switch operated and has five decade dials and four pairs of ratios, the accuracy of adjustment is ±0.01 per cent.

Early deliveries — Full details from

116 Windmill Road, Croydon, Surrey
Telephone : THOrnton Heath 4025



Quartz Crystals of any shape and size cut and ground precisely to specification and coated, if required, with Gold, Silver, Aluminium or Rhodium, etc.

BROOKES

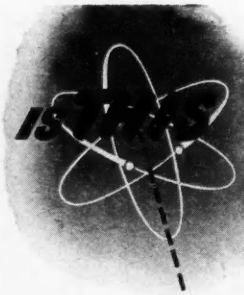
Brookes Crystals Ltd.,

Suppliers to Ministry of Supply, Home Office, B.B.C., etc.

EARLSWOOD ST., GREENWICH, LONDON, S.E.10

Telephone : GREenwich 1828

Grams: Xtals Green London. *Cables:* Xtals London



the answer to *your* problem?

'SINTREX' Electrolytic Iron Powder has solved many problems in electronics. Its exceptional purity gives it excellent electro-magnetic properties—ensuring high permeability and low losses in components such as small transformer cores, pole pieces, etc., for radio, T.V., fluorescent units, measuring instruments and much other equipment.

'SINTREX'
ELECTROLYTIC IRON POWDER

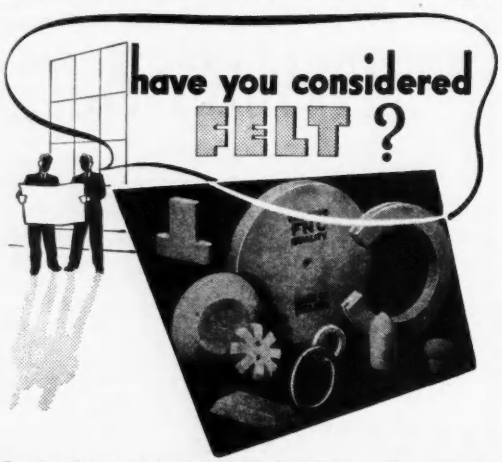
GEORGE COHEN SONS & CO. LTD

BROADWAY CHAMBERS · LONDON · W.6

Telephone: Riverside 4141

THE 600 GROUP

RR/533/IP3



On the 'Mauretania' and the two 'Queens', on railway systems throughout the world, certainly in your own car, Cooper's felt is proving an invaluable material for a surprising number of purposes. Have you considered felt? One of Cooper's experts will be happy to answer any questions.

COOPERS FELT

Please send all enquiries to Head Office and Works:

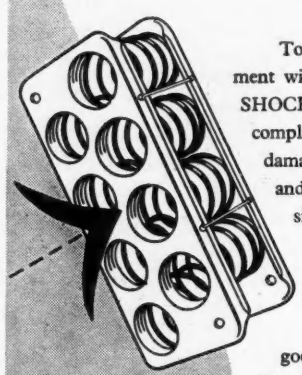
COOPER & CO. (B'ham) Ltd.

BRYNMAWR, BRECONSHIRE

Tel.: Brynmawr 312 *Telegrams: Felting Brynmawr*

Registered Office & Works: Little King Street, Birmingham, 19

Take the **IMP** *out of* **IMPACT**



To protect valuable equipment with the new METPAK SHOCK ABSORBER is the complete insurance against damage in transit. Tested and proved and used extensively by the Ministry of Supply and many industrialists. Why not make sure *your* equipment is received in good condition. Write for full details.

Sole licensed manufacturers:—

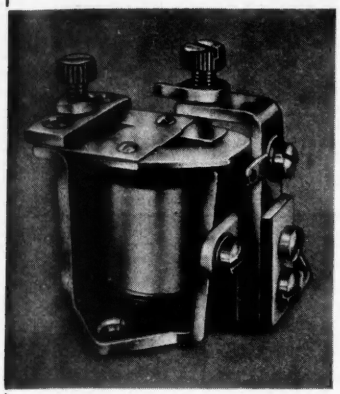
METPAK REGD.

BRAYHEAD SPRINGS LTD.

Full View Works, Kennell Ride, Ascot Berks.

Telephone: Winkfield Row 3115

HIGH SENSITIVE BUZZERS



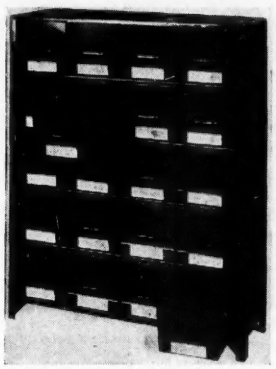
- *Wound from 1.5 to 110 volts*
- *Solid Construction*
- *Quality Materials*
- *Fine-Silver Contacts*
- *Easily Adjustable*
- *Compact in Size*

FOR TELECOMMUNICATION WORK
STANDARD FINISH OR TROPICALISED

Enquiries Invited for :
CHOKES, POLARISED BELLS, INDUCTION COILS

AUTOPHONE LTD.
539/547 WANDSWORTH ROAD,
LONDON, S.W.8. *MACaulay* 2381/2

The 'STOREMASTER' UNIT



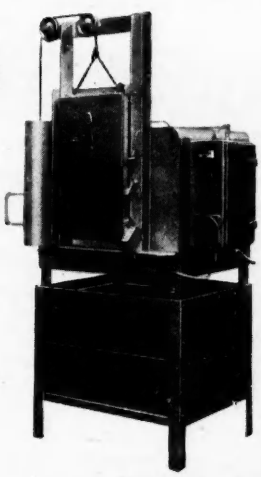
20 DRAWERS

PRICE 14 GNS. ex-works

The complete answer to your small stock storage problems. All-steel, 44" high, 36" wide and 12" deep, finished in bronze green stoved enamel.

N. C. BROWN LTD.
Dept. E.E., EAGLE STEEL WORKS, ROCHDALE RD., EAST HEYWOOD, LANCS. **Telephone : Heywood 69018, 9**

'B-W' Electric FURNACES



The wide range of 'B-W' industrial heating equipment includes many types of industrial furnaces and ovens, large and small.

Temperature ranges and capacities cover all normal needs and special types can be built to requirements.

- **General Purpose**
- **Automatic Control**
- **Various sizes**

Write for details today.

For temperatures up to **1,400°C.**

★

INDUSTRY NEEDS HEAT— YOU NEED 'B-W'

'B-W' PRODUCTS INCLUDE :
- **OVENS**
- **METAL POTS**
- **DIP TANKS**
- **WAX POTS**
- **SALT BATHS**
- **LEAD POTS**

Burlow-Whitney
COOMBE RD., NEASDEN LANE, LONDON, N.W.10. GLA 1152
LONDON OFFICE: 2 DORSET SQUARE, N.W.1 AMB 5485

Quantity production of small automatically made pieces in Steatite, Porcelain and Rutile materials for electric cooking and heating equipment, and telecommunication apparatus.

GEO. BRAY & CO. LTD., Leicester Place, Leeds 2.
Tel. : 20981/3. Grams. : "Bray, Leeds 2"

A·D·S RELAYS Ltd

Late ALEC DAVIS SUPPLIES LTD.

Dept. E.E.

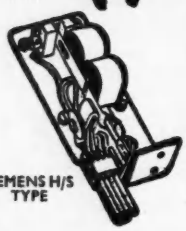
12, STORE STREET,
TOTTENHAM CT. ROAD
LONDON, W.C.1.

Tel: MUSeum 2453/4539

Business Hours:
Monday - Friday 9—5.30
Saturday 9—1

RELAYS

600 or 3,000 TYPE



SIEMENS H/S TYPE

D.C. COIL RESISTANCE

3,000 TYPES : 1.9Ω to 80,000Ω
600 TYPES : 0.4Ω to 9,200Ω.

ALSO LARGE STOCKS OF DOUBLE & TRIPLEWOUND AND SLUGGED COILS.

CONTACTS

3,000 TYPES : up to 8 sets.
600 TYPES : up to 4 sets.
3,000 TYPES: Make (M), Break (B), in Twin - silver, Twin - platinum, Dome-silver (2 amp.). Tungsten (5 amp.), and Flat-silver (8 amp.). Change-over (C), in all but Tungsten: Make-Before-Break(K), in Twin-silver and Twin-platinum.

600 TYPES : (M), (B) and (C), in Twin-silver and Twin-platinum.

SPECIAL
High resistance slugged coils (up to 10,000 OHMS with 1" slug) now available.

THOS. ALLNUTT & CO.

Metal Thread and Wood Screws. Turned or Pressed Nuts, Plain, Shakeproof and Spring Washers for all purposes. Wing Nuts.

SOLDERING TAGS AND EYELETS

LEE CHAPEL LANE
LANGDON HILLS, Essex

Telephone: LAINDON 122
Home & Export

★ENGLAND'S
SMALLEST
TRANSFORMER

Keeping pace with modern developments, Belclere have developed a range of small and miniature transformers for all input, output and interstage purposes. The type "O" transformer, shown above approximately full size, has been specially designed for an all-transistor hearing aid. It measures only ⅜in. x ⅜in. x ¼in. Inductance 4 H at 0.4 mA. Mumetal core. Supplied with screening can if desired Write for literature covering full range.

JOHN BELL & CROYDEN 117 HIGH STREET OXFORD

If you need

a small **METAL PRESSING**
for your product, why not consult us ?

● ● ●

We specialise in light precision presswork in all metals for the Electrical Trades

QUOTATIONS BY RETURN

BIRMINGHAM SPECIALITIES LTD.
80-81 BATH STREET BIRMINGHAM 4
Phone: CENTRAL 2492

"SANOID" FIRST AID

For over fifty years we have studied and supplied the specialised First Aid requirements of Industry. We believe our efforts have been of advantage to those we are privileged to serve, as on many occasions we have been able to meet the particular needs of various industries and conditions.

May we help you? Our wide experience is at your service, and we should be pleased to quote you for your specific requirements.

A PRODUCT OF
Cuxson Gerrard & Co. Ltd.
OLDBURY BIRMINGHAM

FIRST AID SPECIALISTS
ESTABLISHED 1878

ELECTROPLATERS TO THE ELECTRONIC INDUSTRY

ATLAS

are now well established as the premier Electro-Platers for the metal finishing of ELECTRONIC COMPONENTS. Our work is laboratory controlled resulting in a high standard of finish.

We are in a position to undertake large quantity production of silver plating on light alloy or other base materials,

●

Service is also available for Electro-forming of Wave Guides or intricate shaped components,

●

ATLAS
PLATING WORKS Ltd
Avenue Road, Acton,
London, W.3.
Telephone: ACOrn 1102

APW

FREE — A VALUABLE BOOK which details the wide range of Engineering and Commercial courses of modern training offered by E.M.I. Institutes.

Engineering courses include training for : City and Guilds Grouped Certificates in Telecommunications; A.M.Brit.I.R.E. Examination; Radio Amateur's Licence, Radio & Television Servicing Certificates, General Radio and Television Courses, Radar, Sound Recording, etc. Also Courses in all other branches of Engineering.

Courses from £1 per month

E.M.I. Institutes

The only Postal College which is part of a world-wide Industrial Organisation.

POST THIS COUPON TODAY

Please send, without obligation, the FREE book.
E.M.I. Institutes, Dept. 11, 43 Grove Park Rd., Chiswick, London, W.4.

Name.....

Address.....

ICI8

PLASTIC MOULDERS

A.I.D. Approved

Phone High Wycombe 1921/2

COMPRESSION TRANSFER INJECTION

Over 50 PRESSES MODERN TOOL ROOM

ELCO PLASTICS LTD. High Wycombe. Bucks.

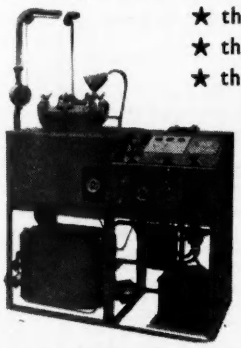
IF *YOUR* PROBLEM IS

COIL IMPREGNATION

The BLICKVAC HIGH-VACUUM IMPREGNATOR

meets the rapidly growing demand for high-vacuum impregnation.

Full range of models available to meet the needs of



★ the large-scale Producer
★ the Research Laboratory
★ the small Rewind Shop

BLICKVAC UNITS MEET THE MOST STRINGENT SPECIFICATIONS.

Outstanding features :

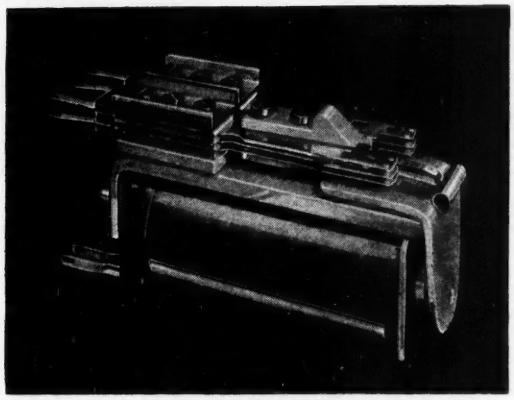
- Ease in control
- Simple attachment of auxiliary autoclaves
- Best quality fittings
- Fully demountable to facilitate cleaning

UNEQUALLED FLEXIBILITY AND PERFORMANCE.

Units available for :

VARNISH — BITUMEN
WAX — POTTING RESINS

If your problem is Coil Impregnation, CONSULT BLICKVAC
Write today to Hamilton Road Works, Hamilton Road, S.E.27
Associated with Blick Time Recorders Ltd., Blick Engineering Ltd.



RELAYS *for* TELECOMMUNICATIONS

A Quality Relay with Sensitive High Efficiency Magnetic Circuit similar to G.P.O. 3000 type. Improved design Coil Tags. Armature fixed with special clip for easy removal.

CHARACTERISTICS.

CONTACTS. Nickel Silver Springs with Silver, Silver Alloys, Platinum or Heavy Duty Elkonite Contacts as required. Up to six sets of Change-over or eight sets of Make or Break Contacts.

COIL. Resistance from 1 to 100 000 ohms. Up to three windings on one coil.

Enquiries to:

AUTOPHONE LIMITED

539/547, Wandsworth Road, London, S.W.8
MACAULAY 2381/2.

INDUSTRIAL PROBLEMS

No. 11. DETAILED EXAMINATION, SETTING AND TIMING OF INTRICATE MACHINERY.

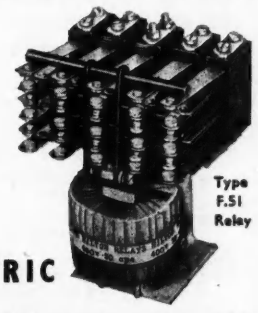
Machinery faults produced at high speeds are not usually present when running machines slowly for visual examination and checking.

For quick and effective examination at high speeds SLOW MOTION AND STATIONARY images can be obtained by using DAWE STROBOSCOPES.

For further details and supply consult —

A. C. FARNELL LTD., 15 Park Place, Leeds, 1.
Telephone: Leeds 23958/9.
(*Official Agents for DAWE INSTRUMENTS*)

A HEAVY DUTY TILTING ARMATURE A.C. RELAY DESIGNED FOR RAPID & CONTINUOUS OPERATION WITHOUT DETERIORATION.

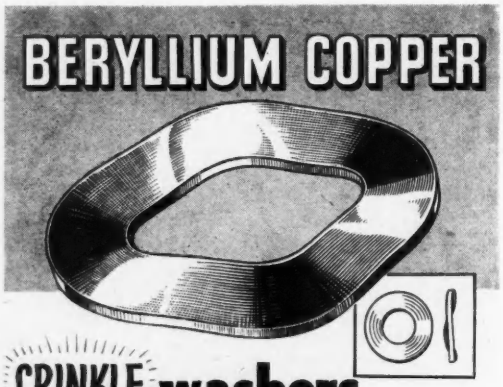


Type F.51 Relay

HILTON ELECTRIC COMPANY

52, POOL ST., WOLVERHAMPTON. *Phone: 22783*

BERYLLIUM COPPER



CRINKLE washers

Heat treated and plated, giving corrosion resistance with high degree of recovery in relation to load, and resistance to "set". Spring locking action suitable for electronic and instrument components. Size range ½" to 8 B.A.

Prices and samples sent on request.

CONTRACTORS TO THE ADMIRALTY • MINISTRY OF SUPPLY • & OTHER GOVERNMENT DEPTS.

TRADE MARK

DAVID POWIS & SONS LTD.

FORWARD WORKS · SPARKBROOK · BIRMINGHAM 11 · PHONE VIC 1264-8

PRECISION ROTARY INDUCTORS

are now finding wide application to problems associated with automatic control, remote indication, electrical torque transmission, etc.

Please write for brochure giving details of our range of :

MAGSLIPS SELSYNS
LINEAR INDUCTIVE POTENTIOMETERS (IPOTS)
SINE-COSINE POTENTIOMETERS

and many other items of interest to the Electronic Engineer concerned with Servo and Computing Systems.

Servo & Electronic Sales Ltd.

1, Hopton Parade, Streatham High Road London, S.W.16

STReatham 6165

"SPEARETTE" MINIATURE VALVE PIN ALIGNING TOOLS

TYPES AVAILABLE FOR
B7G - B8A - B9A
VALVE BASES

SPEAR ENGINEERING CO. LTD.
TITAN WORKS, WARLINGHAM, SURREY
Telephone : Upper Warlingham 2774

SPECIALISTS IN PACKING ELECTRONIC EQUIPMENT

SYNTHETIC SUPPLIES LTD.

ALBERT MILLS · SILK STREET
ECCLES · MANCHESTER
Telephones : ECCles 1720 & 3225,6

Casemakers and general joinery : Packing and Preservation : Shipping and Forwarding Agents: Warehousing

Contractors to the Admiralty, Air Ministry, Ministry of Supply & G.P.O. Approval No. B23789/40

TRANSFORMERS
CHOKES
SOLENOIDS
COILS

- **MADE TO YOUR SPECIFICATION IN ANY QUANTITY AT COMPETITIVE PRICES**
- **HIGHEST GRADE MATERIALS AND INSULATIONS USED**
- **DIE CAST FRAMES OR MOUNTING BRACKETS MADE FOR ALL FITTINGS**

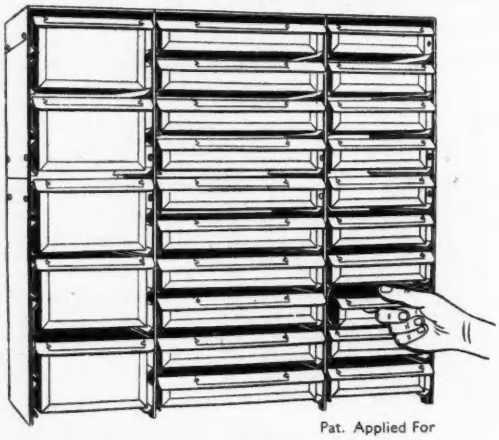
Send your enquiries to –

W.L.R.S. LTD.

DELTA HOUSE, 30 FAUCONBERG RD., CHISWICK, W.4
CHIS. 0384

. . . . those small components are important

Keep them in RECEPTORAK. Well-stored, immediately accessible. Self-build tray storage units from only 5 basic parts.



Pat. Applied For

Tray sizes 5⅜" wide × 1¼" deep inside, 5⅜" wide × 3½" deep inside, 8⅜" wide × 1½" deep inside.

Write for details of RECEPTORAK to Dept. E.E.3.

THE RANDALL ORGANISATION

(JAMES H. RANDALL & SON LTD.)
PADDINGTON GREEN WORKS, LONDON, W.2.
AMBassador 1661.

TELEVISION-BELGIUM

Belgian Wholesalers—Importers
request contact with
Makers of British Television Sets
willing to manufacture according to Belgian Standards and to grant sole representation and distribution for Benelux Countries.

Write to :—

ESTABLISSEMENTS HENRI HORN
82 Avenue du Port, Brussels, BELGIUM

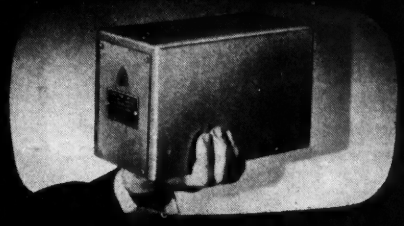
Established 25 years

TECHNICAL BOOKS

H. K. LEWIS & Co. Ltd. invite inspection of their stock of books on all branches of Radio and Electrical Engineering. Catalogue on request.
LENDING LIBRARY : Technical and Scientific. Annual Subscription from TWENTY-FIVE SHILLINGS
Prospectus Post Free on Request.
THE LIBRARY CATALOGUE revised to December, 1949, containing a classified Index of Authors and Subjects. To subscribers, 17s. 6d. net. To non-subscribers, 35s. net. Postage 1s. 3d. Supplement 1950-52. To subscribers, 3s. net. To non-subscribers, 6s. net, postage 6d.

LONDON: H. K. LEWIS & Co. Ltd., 136 Gower St., W.C.1
Telephone: EUSton 4282 (7 lines)

A NEW SMALL AUTOMATIC A-C VOLTAGE STABILISER



The ASR-1150 *Weighs* 11 lbs.
Measures $8\frac{1}{2} \times 4\frac{1}{2} \times 5$ *Price only* £24

This new Stabiliser will handle loads up to over 1 kilowatt—having an output of 5 amperes at (usually) 230 volts. As a general rule it weighs only about 1 10th of the so-common "choke-condenser" types offered by some competitors.

ASR-1150 is totally unaffected by changes in the mains frequency. It is also quite insensitive to load changes, working equally well from 0 % to 100 % full load (1.15 kVA). It has no large, high a-c working rating capacitors—which fail regularly in "resonated" types of Stabiliser, and which are very expensive to replace.

May we send you a copy of our new 20-page Supplementary Catalogue published July 1953. Just ask for Catalogue V-549-S.

ASR-1150 is merely one of an entirely new range of A-C Stabilisers, ranging from 200 VA to as high as 50 kVA—all dealt with in Catalogue V-549-S.

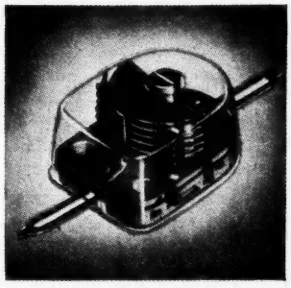
CLAUDE LYONS LTD

180 182 TOTTENHAM COURT ROAD, LONDON, W.1
OR 76 OLDHALL STREET, LIVERPOOL, 3, LANCASHIRE

Excellence in design..

AIR DIELECTRIC TRIMMER

(Protected by Acetate Case)



TYPE APPROVED CAT. A. No. 464

Capacities from 4 to 70pF in voltages of 500 and 1000 D.C. Width 16.5 mm. Length 22 mm. Acetate dust cover optional. Insulation over 10,000 megohms. Power factor less then ·001.

OXLEY

DEVELOPMENTS CO. LTD.
ULVERSTON, NORTH LANCS. Tel: Ulverston 3306

P.V.C. SLEEVINGS
INSULATED WIRE AND FLEX

PLASTICABLE LTD

(A.I.D. APPROVED)

Hawley Lane, Farnborough Hants.

Phone: FARNBOROUGH, HANTS 85

We Specialise in the design and development of prototypes and have immediate **Capacity Available** for small batch production of :—

ELECTRONIC APPARATUS
and for quantity production of
INSTRUMENT ASSEMBLIES
GEARS and PINIONS

PRECISION TURNED PARTS FROM SWISS AUTOMATICS

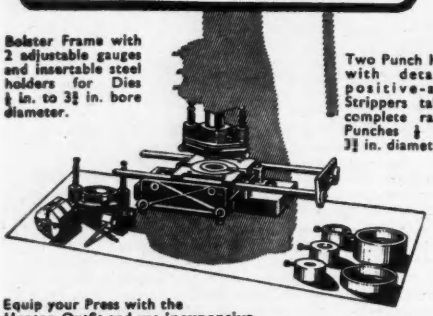
ROBERT PRINGLE & SONS
36/42 Clerkenwell Road, London, E.C.1
Telephone: CLErkenwell 2341

REDUCE YOUR PRESS TOOL COSTS

THE HUNTON UNIVERSAL BOLSTER OUTFIT FOR SHEET METAL PIERCING AND BLANKING ON FLY PRESSES

Bolster Frame with 2 adjustable gauges and insertable steel holders for Dies ¼ in. to 3½ in. bore diameter.

Two Punch Holders with detachable positive-action Strippers take the complete range of Punches ¼ in. to 3½ in. diameter.



Equip your Press with the Hunton Outfit and use inexpensive standardised Punches and Dies ¼ in. to 3½ in. diameter obtainable from stock—in 1/64 in. sizes—when you need them. Standardised Tools also available at short notice for Square, Oblong and other shapes, Louvre Forming (up to 8 in. long), Corner Notching, Corner Radiusing, Angle Iron Notching and Piercing, etc.

Get the outfit now—Buy Punches, Dies and tools as you need them

Descriptive brochure and prices on request.

HUNTON LIMITED

Phoenix Works, 114-116, Euston Road, London, N.W.1

Telephone: Euston 1477 *Telegrams:* Untonexh, London

A.I.D. APPROVED

VALVE RETAINERS FOR ALL VALVES

HART BRITISH

COIL WINDERS TO M.O.S.

H. COLLARD HART LTD.

Specialists in the manufacture of coils, H.F. & I.F. chokes, etc., and small electronic and electrical components to customers specification.

WEST CRAVEN STREET, SALFORD 5.

LAMALAC INSULATION

SYNTHETIC RESIN LAMINATED MATERIALS

Sheet, Rod and Tube in all dimensions, Bobbins & Coil Formers to any specification

MICA AND MICANITE SHEET AND MANUFACTURED PARTS

MICA & MICANITE SUPPLIES LTD.,

BARNSBURY SQUARE, LONDON, N.1.

Phone: NORth 3032/5 Grams: MICASULIM, LONDON

INSULATION

Our products include—
Presspahn and Leatheroid ; Pressboard ; Vulcanized Fibre ; Cable and Red Rope Paper ; Bakelite and Ebonite ; Varnished Paper and Tapes ; Varnished Silks and Tapes ; Varnished Glass and Tapes ; Varnished Cambric, Silk, Glass and P.V.C. Sleevings ; Cotton Tapes, Webbings and Sleeving ; Chatterton Compound ; Adhesive and Rubber Tapes.

PRESSPAHN, LTD.

Bradford, Yorks, England
Established 1900

REGISTERED ELECTRICAL WELLSTEAD INSULATION TRADE MARK

Telephone:
Bradford 25135 (Pvt. Br. Ex.)
Telegrams & Cables:
"Presspahn, Bradford"

This is our Silver Jubilee Year

As manufacturers of small components in the field of Electronics and Electrical Engineering, we have experience behind us now extending over 25 years. We specialise in Mouldings to your own drawings and specifications for which our tool-room is fully equipped.

Thermo-Setting Plastic Mouldings

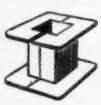


Illustration of bobbin shown full size.

Core dimensions: 0·126" × 0·103"
also: 0·126" × 0·123"
Depth 0·285"

Very small articles moulded with accuracy and precision.

HARRISON BROS

PLASTICS LIMITED

39-43, BRANSTON ST · BIRMINGHAM 18

Telephone: COLmore 4270 **Telegrams:** "ARISUN, Phone, Birmingham"

'Radiospares' Quality Parts

The Service Engineer's First Choice

GEORGE WILDEN LTD
Western Works, 170 Pitsford Street,
Birmingham, 18. (*NOR* 2714)

White Ad 2794

"COMPONENT PARTS"

FOR THE RADIO, RADAR, TELEVISION AND ELECTRONIC INDUSTRIES.

We specialise in the manufacture of Coiled and Bent Wires of every description. Plug and Socket Contacts. Pins. Inserts. Connecting and Soldering Wires. Strip Forming and Light Metal Stampings.

Inquiries Invited. *Prompt Attention.*

THE WHITECROFT PIN MANUFACTURING CO. LTD
WHITECROFT, GLOS.
Telephone: Whitecroft 308.

FOR ECONOMIC & ACCURATE SOLDERING

You'll be wiser to use **Wolf** *Electric*
SOLDERGUNS & SOLDERING IRONS

FIRST CHOICE IN ELECTRIC SOLDERGUNS!

Designed for faster, cheaper and easier soldering, Wolf Solderguns and Soldering Irons meet all requirements. In addition to the Type 51 trigger feed soldergun which is superb for rapid repair or assembly jobs, there are eight other models to choose from, including three with straight handles. Rapid constant localised heat, low current consumption, perfect balance and utmost dependability are some of the reasons why Industry insists on Wolf.

Obtainable from all leading tool merchants. Fully descriptive brochure free on request.

ALTERNATIVE TYPES AVAILABLE

SOLDERGUNS

SOLDERING IRONS

WOLF ELECTRIC TOOLS LTD · PIONEER WORKS · HANGER LANE · LONDON · W.5
(A PERIVALE SKIL ● Product) BIRMINGHAM MANCHESTER LEEDS BRISTOL NEWCASTLE GLASGOW

E.H.T. EQUIPMENT

The High Voltage Department of Rivlin instruments, Ltd., specialises in the design and production of E.H.T. Generators of all types for—

TELEVISION
INDUSTRIAL
and
MEDICAL
APPLICATIONS.

Most requirements can be met out of our range of standard units which comprise complete equipments at very moderate cost. Specifications cover voltages up to 60kV (in some cases, even higher) with currents up to 2mA. Regulation can be better than 0.1 per cent if required and outputs stabilised against mains variations.

Inquiries for large or small quantities receive prompt attention. Speedy delivery can usually be given.

SPECIALISTS IN THE DESIGN AND MANUFACTURE OF HIGH-GRADE ELECTRONIC INSTRUMENTS

RIVLIN INSTRUMENTS Ltd.
7a [MAITLAND [PARK [VILLAS
LONDON, N.W.3
Telephone: GULliver 2960

AN ESTABLISHED AND WELL-KNOWN ORGANISATION actively engaged in the design and manufacture of wideband UHF and VHF radio systems suitable for the transmission of multi-circuit carrier telephone signals or television signals has immediate vacancies for :—

(*a*) **SENIOR ENGINEERS**—University degree or equivalent with at least two years industrial experience in the radio communications field.

(*b*) **ASSISTANT ENGINEERS**—preferably with similar academic qualifications but not necessarily the same length of industrial experience.

(*c*) **DESIGNER/DRAUGHTSMEN** — with experience in radio communications, telecommunications or electronics.

(*d*) **DRAUGHTSMEN**—with experience in telecommunications or electronics.

(*e*) **INSTRUMENT MAKERS/WIREMEN** —for building experimental laboratory equipment.

These appointments are permanent and pensionable, and offer exceptional opportunities for advancement to fully trained men able to act with a minimum of supervision.

Applications in detail should be addressed to Box No. W. 3130

INDEX TO ADVERTISERS

Acheson Colloids Ltd 59
A.D.S. Relays Ltd. 96
Aero Research Ltd. 15
Airmec Ltd. 41
Allnutt & Co., Thos. 96
All-Power Transformers Ltd. 40
Antex Ltd. 60
Atlas Plating Works Ltd. 96
Automatic Coil Winder & Equipment Co., Ltd., The 19
Automatic Telephone & Electric Co., Ltd. 39
Autophone Ltd. .. .. .. 95 and 97

Baldwin Instrument Co., Ltd. .. 69
Barlow-Whitney Ltd. 95
Barrington Products Ltd. 69
B.B. Chemical Co. 77
Bell & Croyden, John 96
Belling & Lee Ltd. 38
Birmingham Specialities Ltd. 96
Blickvac Ltd. 97
Bray & Co., Ltd., George 95
Braybead Springs Ltd. 94
British Communications Corporation Ltd. 37
British Electric Resistance Co., Ltd. 83
British Insulated Callender's Cables Ltd. 49
British Thomson-Houston Co., Ltd. 17
Brooke's Crystals Ltd. 94
Brown Ltd., N. C. 95
Bruel & Kjaer 83
Bullers Ltd. 36

Chance Bros., Ltd. 84
Chapman & Hall Ltd. 129
Cinema-Television Ltd. 35
Cleaver-Hume Press Ltd. 93
Cohen, Sons & Co., Ltd., George .. 94
Cole Ltd., E. K. 5
Collard Hart Ltd., H. 100
Cooper & Co. (Birmingham) Ltd. .. 94
Counting Instruments Ltd. 84
Croydon Precision Instrument Co. .. 93
Cuxson, Gerrard & Co., Ltd. 96
Cygnet Joinery Ltd. 93

Davis (Relays) Ltd., Jack 93
Davis, Wynn & Andrews Ltd. 86
Dawe Instruments Ltd. 85
Derby & Co., Ltd. 92
Dobbie McInnes Ltd. 85
Donovan Electrical Co., Ltd. 92
Drayton Regulator & Instrument Co., Ltd. 86

Edison Swan Electric Co., Ltd., The Cov. ii and 55
Egen Electric Co., Ltd. 77
Elco Plastics 97
Electrical Instruments Co. (Hillington) Ltd. 88
Electro-Methods Ltd. 87
Electronic Engineering Monographs 86 and 128
Electrothermal Engineering Ltd. .. 88
Elliott Bros. (London) Ltd. 33
E.M.I. Institutes Ltd. .. .. 87 and 99
Enthoven & Sons Ltd., H. J. Cov. i and 30
Ericsson Telephones Ltd 31
Erie Resistor Co., Ltd. 51
Etablissements Henri Horn 99
Evans Electronics Developments Ltd. 87
Ever-Ready Co. (Great Britain) Ltd. 89
Evershed & Vignoles Ltd. 25

Farnell Ltd., A. C. 97
Ferguson Radio Corporation Ltd. .. 82
Ferranti Ltd. 23
Firth Vickers Stainless Steels Ltd. .. 82
Fox Ltd., P. X. 28

Gardner's Radio Ltd. 81
Garrard Engineering & Manufacturing Co., Ltd., The 80
General Electric Co., Ltd., The .. 26
General Engineering Co. (Radcliffe) Ltd. 24
Goodman's Industries Ltd. 21
Graham Gear Co., Ltd. 88

Haddon Transformers Ltd. 81
Hampton Works (Stampings) Ltd. .. 89
Harrison Bros. (Plastics) Ltd. 100
Hassett & Harper Ltd. 22
Henley's Telegraph Works Co., Ltd., W. T. 89
Hill Ltd., C. & L. 20
Hilton Electric Co. 97
Hivolt Ltd. 18
Hunt Ltd., A. H. 16
Hunton Ltd. 100

Isotope Developments Ltd. 92

Kelvin & Hughes Ltd. 79

Langham Thompson Ltd., J. .. 11 and 32
Lewis & Co., Ltd., H. K. 99
Lewis Spring Co., Ltd. 79
Linread Ltd. 62
Londex Ltd. 67
London Electric Wire Co. & Smiths Ltd. & Vactite Wire Co., Ltd. .. 67
London Office Machines Ltd. 68
Lyons Ltd., Claude 99

Magnetic & Electrical Alloys Ltd. .. 71
Marconi Instruments Ltd. 43
Metachemical Processes Ltd. 9
Mica & Micanite Supplies Ltd. .. 100
Midland Silicones Ltd. 42
Muirhead & Co., Ltd. 45
Mullard Ltd. .. 14, 27, 34, 54 and 65
Multicore Solders Ltd. .. .. Cov. iv.
Murex Ltd. 102

Nagard Ltd. 71
Neill & Co. (Sheffield) Ltd., James .. 70
New Electronic Products Ltd. .. 68

Omicron (Electronics) Ltd. 70
Oxley Developments Ltd. 99

Painton & Co., Ltd. 63
Philips Electrical Ltd. 72
Plannair Ltd. 3
Plasticable Ltd. 95
Powis & Sons Ltd., David 98
Precision Rubbers Ltd. 3
Pressphn Ltd. 100
Pringle & Sons (London) Ltd., Robert 99
Pye Ltd. 58
Pye Ltd., W. G. 72

Radio Resistor Co., Ltd. 57
Radiospares Ltd. 100
Ragosine Oil Co., Ltd. 90
Randall & Son, Ltd., James, H. .. 98
Ratcliffe (Rochdale) Ltd., F. S. .. 53
Redifon Ltd. 80
R.E.M.E. Hq. Army Emergency Reserve 90
Rivlin Instruments Ltd. 101

Salford Electrical Instruments Ltd. .. 74
Sankey & Sons Ltd., Joseph 74
Saunders-Roe Ltd. 56
Scott & Co., Ltd., A. C. 60
Servo & Electronic Sales Ltd. 98
Servomex Controls Ltd. 13
Smith & Sons Ltd., W. H. 129
Solartron Laboratory Instruments Ltd. 7
Southern Instruments Ltd. 75
Spear Engineering Co., Ltd. 98
Standard Telephones & Cables Ltd. 12, 29 and 66
Steatite & Porcelain Products Ltd. .. 48
Steatite Insulations Ltd. 50
Sugg & Co., Ltd., William 76
Sullivan Ltd., H. W. 75
Synthetic Supplies Ltd. 98

Telegraph Condenser Co., Ltd. Cov. iii
Telegraph Construction & Maintenance Co., Ltd. 76
Thermo-Plastics Ltd. 47
Thomas (Richard) & Baldwin Ltd. .. 52
Transradio Ltd. .. .. 78 and 90
Trumeter Co., Ltd. 78
Truvox Engineering Co., Ltd. 91
Twentieth Century Electronics Ltd. .. 61

Unbrako Socket Screw Co., Ltd. .. 46

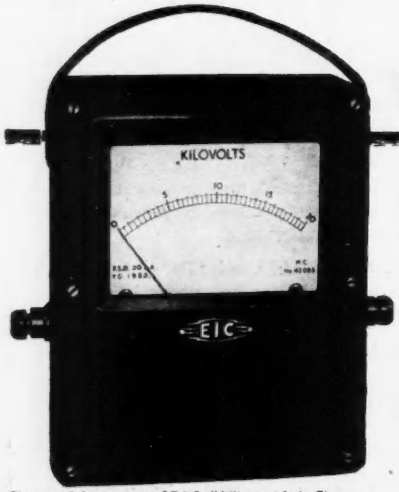
Venner Accumulators Ltd. 44

Webb's Radio 73
West London Rewind Service Ltd. .. 98
Whitecroft Pin Manufacturing Co., Ltd., The 101
Wilcox & Co., Ltd., Edward 73
Wilden Ltd., George 101
Wilkinson's Tools Ltd. 91
Woden Transformer Co., Ltd. 91
Wolf Electric Tools Ltd. 101
Woods of Colchester Ltd. 64

MUREX 'SINCOMAX' MAGNETS

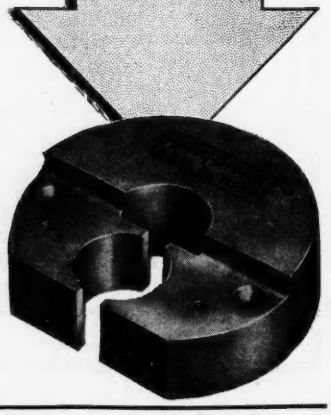
ARE USED IN

E.I.C. INSTRUMENTS



Photograph by courtesy of E.I.C. (Hillington) Ltd., Glasgow

The high magnetic stability and strength of 'Sincomax' magnets makes a robust job even of a sensitive Microammeter. In this application as in many others Murex Sintered Magnets continue to give accurate and reliable service.



MUREX LIMITED *(Powder Metallurgy Division)*

RAINHAM • ESSEX • *Rainham, Essex 3322*

London Sales Office: Central House, Upper Woburn Place, W.C.1. *Euston 8265*

Printed in Great Britain by The Press at Coombelands, Ltd., Addlestone, Surrey, for the Proprietors, Morgan Brothers (Publishers), Ltd., 28, Essex Street, Strand, W.C.2. Registered for Transmission by Canadian Maga-ine Post.

This
ordinary
requireme
R.C.L.13
with whi
nated, ha
non-void
ionisation
the upper

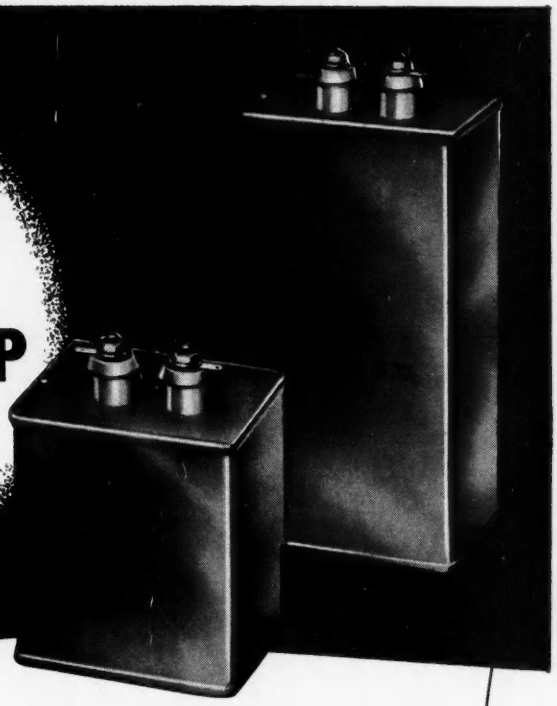
D.C.Wk
200 V.
250 V.
400 V.
600 V.
600 V.
800 V.
800 V.
1000 V.
1200 V.
1500 V.
2500 V.
2500 V.
5000 V.
7500 V.
10,000 V.

SPE

MARCH

FOCUS ON LEADERSHIP

'ISCONOL'



This range has several advantages over the ordinary Paper Condenser and complies with the requirements of Inter-Service Specification and R.C.L.131. Our exclusive mineral oil "Visconol", with which the paper dielectric plates are impregnated, has two outstanding characteristics: it is non-void forming, and therefore gives higher ionisation voltages, and its chemical stability raises the upper working temperature limit to 100°C.

Apart from having a greater margin of safety, these "Visconol" Condensers are more versatile than our ordinary tropical paper types. Two methods of mounting are available: Types 141 - 155 have detachable brackets, conforming to R.C.L.131, and types 120-134 have T.C.C. pattern soldered-on feet.

Capacity tolerance is ±20%. Voltage ratings below are for 70°C.

D.C.Wkg.	0.05 μF.	0.1 μF.	0.25 μF.	0.5 μF.	1 μF.	2 μF.	4 μF.	8 μF.
200 V.	—	—	—	—	—	CP141H	CP144H	CP147H
250 V.	—	—	—	CP120K	CP120K	CP121K	CP122K	CP123K
400 V.	—	—	—	CP124Q	CP124Q	CP125Q	—	CP127Q
600 V.	—	—	—	—	CP128T	CP129T	CP130T	CP127T
600 V.	—	—	—	—	CP142T	CP144T	CP147T	CP150T
800 V.	—	CP128V	CP128V	CP128V	CP131V	CP130V	CP132V	—
800 V.	—	—	—	—	CP143V	CP146V	CP149V	CP152V
1000 V.	—	—	CP141W	CP142W	CP145W	CP147W	CP149W	CP153W
1200 V.	—	CP131X	CP131X	CP131X	CP130X	CP132X	CP133X	CP134X
1500 V.	—	CP141GO	CP142GO	CP145GO	CP147GO	—	—	—
2500 V.	—	CP144KO	CP146KO	CP120K	CP120K	CP121K	CP122K	CP123K
2500 V.	—	—	—	CP147KO	CP150KO	CP153KO	CP154KO	CP155KO
5000 V.	—	CP148SO	CP151SO	CP153SO	CP154SO	CP155SO	—	—
7500 V.	—	CP151UO	CP153UO	CP154UO	CP155UO	—	—	—
10,000 V.	CP151WO	CP153WO	CP154WO	CP155WO	—	—	—	—

Fully dimensioned schedule available on request.

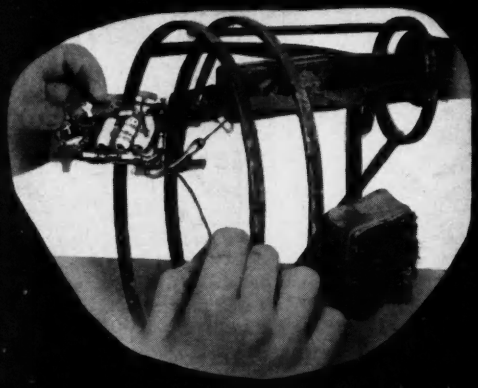
TCC

SPECIALISTS IN CONDENSERS SINCE 1906

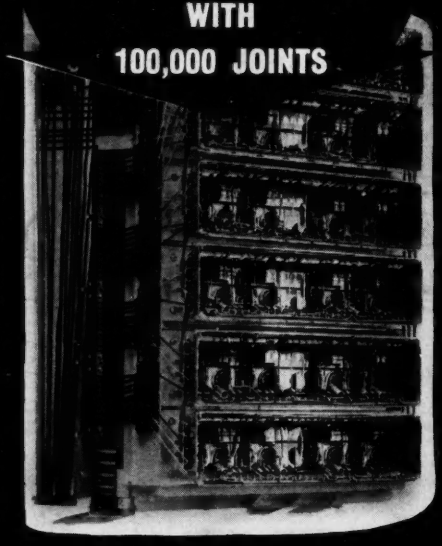
THE FINEST CORED SOLDER IN THE WORLD

For everything to do with soldering

FROM A HEARING AID
WITH
100 JOINTS



TO A DIGITAL COMPUTER
WITH
100,000 JOINTS



Reliability of soldering processes is achieved by use of Ersin Multicore Solder which for nearly 15 years has been preferred by leading manufacturers in Europe and the U.S.A. It is supplied as standard containing three cores of non-corrosive Ersin Flux. Ersin Flux is a high-grade resin which has been chemically processed to increase its fluxing action, while still retaining its non-corrosive properties. It makes precision soldering quicker and more economical — not only preventing oxidation during soldering, but actually cleaning the surface to be soldered. Approved by A.I.D., A.R.B. and G.P.O. Fully meets U.S. Federal specifications. Available in 2 flux percentages.

Cat. Ref. No.	Alloy Tin/Lead	S.W.G.	Approx. Length per carton
C 16014	60/40	14	21 feet
*C 16018	60/40	18	55 feet
C 14013	40/60	13	19 feet
C 14016	40/60	16	38 feet

*Specially recommended for television work.

SIZE 1 CARTON
5/- (SUBJECT)

Multicore products for specific uses

ALLOYS —made in all the usual Tin/Lead alloys as follows:—60/40, 50/50, 45/55, 40/60, 30/70, 20/80.

SPECIAL HIGH AND LOW MELTING POINT SOLDERS. Ersin Multicore is available in the following special alloys, all containing 3 cores of Ersin Flux:—
Type T.L.C. Melting Point 145°C.
Type L.M.P. Melting Point 179°C. Avoids 'pick-up' of silver when soldering ceramics.
P.T. Melting Point 232°C. When lead-free solder is required.
COMSOL. Melting Point 296°C. Extra high melting point soft solder.

GAUGES. Ersin Multicore Solder is made as standard for factory use in gauges between 10-34 s.w.g. as follows:—10, 12, 13, 14, 16, 18, 19, 20, 22, 24, 26, 28, 30, 32 and 34 s.w.g.

FLUXES. Ersin Multicore Solder is supplied in 2 flux percentages and in the following flux types:—

N. Flux contains Pentacol. Unless otherwise ordered, all Ersin Multicore Solder is supplied with this type of flux.

3E Flux. The original Ersin Flux formulation. Has been supplied for more than 14 years.

R2 & R3 Fluxes. Halide and Chloride free fluxes for modern production soldering process calling for this type.

L Flux. Suitable for high speed machines and particularly Lamp production.

2L Flux. As Type L but with only 2.2% flux content.

Type 362 Flux. Extremely fast A.I.D. approved flux. Latest Multicore development.

RINGS. Butt-jointed solder rings in Ersin Multicore Solder Wire or precision made Solid Solder Wire can be supplied in bulk quantities. Gauges—dependent upon the diameters specified—cover the range from 10 to 22 s.w.g.

TAPE SOLDER. With or without flux cores. Packed on 3½-lb. reels in widths from ⅛"-¾" and thicknesses from .005".

SEPARATE FLUXES. For dipping purposes or other processes where it is not convenient to use Ersin Multicore Solder, Ersin non-corrosive Flux is available in liquid form. Approved A.I.D. and D.T.D. 599 specifications. Ersin Jelly Flux with a high viscosity consistency is also available.

ARAX MULTICORE SOLDER. For non-electrical work and particularly for jointing metals. Arax Multicore Solder is supplied with 2 cores of acid-free flux with washable flux residue.

SOLID SOLDER WIRE. For the comparatively few soldering processes where solid wire is required instead of Multicore solders, supplies are available to special order of Multicore Precision Made Solid Wire in all alloys.

FLUID SOLDERS. *Araxolder* in paint or cream consistency with washable flux residue. A similar product with Ersin non-corrosive flux is also supplied.

MULTICORE SOLDERS LTD., MULTICORE WORKS, HEMEL HEMPSTEAD, HERTS. (BOXMOOR 3636)